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Vessel Biofouling Prevention and Management Options Report

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Vessel Biofouling Prevention and Management Options Report

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16. Abstract (MAXIMUM 200 WORDS) This report assesses the state of technology and regulatory initiatives relating to in-water hull cleaning of vessels for biofouling remediation. Biofouling is a significant transport method for aquatic nuisance species (ANS), with ships and boats as the carriers. Information was gathered through internet research, review of a prior USCG report, and interviews of stakeholders in government, academia, equipment vendors, diving companies, and the commercial shipping industry. Many of the interviews took place in person at a government-sponsored conference covering in-water hull cleaning. Regulatory efforts are fragmented internationally and among state and local jurisdictions, with governments taking different approaches, and with regulations in various stages of development. Management practices are in place, proven technological solutions are commercially available, and new approaches are under development. Despite advances however, optimal solutions are elusive because ship operators and equipment manufacturers do not have clear standards or certification requirements for design or management. Biofouling solutions are evolving in parallel with the development of requirements. Cost estimates attributed to biofouling regulations vary widely and accuracy is affected by many factors. Among these are the lack of clear regulatory requirements, and the subjectivity inherent in allocating costs between regulatory compliance and sound business practices.					
17. Key Words biofouling, hull cleaning, aquatic nuisance species (ANS), non-indigenous invasive species (NIS), biofilm, anti-fouling, regulatory, tributyltin (TBT), copper, niche areas, ablative, biocide, Vessel General Permit (VGP), risk-based management			18. Distribution Statement Distribution Statement A: Approved for public release; distribution is unlimited.		
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EXECUTIVE SUMMARY

Marine biofouling is a worldwide problem that affects commercial interests in the form of cost, schedule and maintenance impacts. It also affects the environment, as invasive species can be transported across the world, or from river to pond. For many years, efforts to control aquatic nuisance species (ANS) have focused on ballast water management, and regulations are in place to enforce and document conditions and actions towards that objective. More recently, ongoing research has identified biofouling as a significant mechanism for transporting ANS, with ships and boats as vectors, and there is an increasing awareness that comprehensive efforts are needed in both areas (biofouling and ballast water management) to successfully address ANS.

Biofouling is the attachment of organisms to a surface in contact with water over time, and begins with the growth of a biofilm (slime layer), which occurs on a marine surface under the right conditions. Biofilm growth can progress to a point where it provides a foundation for seaweed, barnacles, and other organisms, some of which may be invasive species. Biofouling management can take the form of preventive actions, such as using anti-fouling coatings for vessels hulls, or remedial actions, such as physically removing biofouling by cleaning the hull in the water or in drydock. Anti-fouling coatings initially focused on incorporating toxic compounds in the paint. Over time, however, these compounds were found to concentrate in harbor sediment, causing environmental concerns, and different approaches to bottom paint have been adopted. This report focuses on in-water hull cleaning, a process that has come under increasing regulatory scrutiny and has fostered the development of new technology to find solutions that produce effective results, while complying with requirements.

Government regulation is developmental as well, with some initial approaches in place, but with many major port areas without guidelines, or with in-water cleaning temporarily halted while regulations progress slowly through the administrative process. Domestically, the United States Coast Guard (USCG) has authority to prevent the introduction and spread of ANS via means that include hull fouling. This authority is granted by the National Invasive Species Act of 1996 (NISA), which amended the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). The USCG has exercised this authority by requiring the regular cleaning of vessel hulls, via regulations in 33 Code of Federal Regulations (CFR) 151.2035. Regulations for in-water cleaning are also in place or under development in a handful of foreign countries and some states, most notably California.

In 2009, the Coast Guard Office of Operational and Environmental Standards (CG-OES), formerly CG-523, funded an overview study on biofouling management; *U.S. Coast Guard Biofouling Assessment, September 2010*. The study noted that shipboard biofouling impacts vessels in two general ways; decreasing revenue and increasing expense. The cost associated with biofouling in the United States (U.S.) was estimated to be as much as \$120B per year. Increased visibility at international and Federal levels, regulatory efforts, and evolving hull coating and cleaning technology created a need for the USCG to update its knowledge of biofouling management practices. Recently, CG-OES called upon the USCG Research and Development Center (RDC) to research information essential for policy and regulation development, concerning criteria/standards for biofouling effluent release to the environment, technology readiness, and overall effect on stakeholders. This tasking led to the current study and this report.

Vessel Biofouling Prevention and Management Options Report

The current state of biofouling regulation is fragmented from international levels to local jurisdictions within the United States. Entities have taken one of two general approaches to biofouling management, developing policies that either 1) recommend and/or require hull management regimes, or 2) require that vessels arrive with “clean” hulls (usually in addition to requiring specific maintenance practices). The International Maritime Organization (IMO), the USCG, Australia, and California are examples of the first approach, requiring a set of anti-fouling practices and ship’s documentation. The underlying assumption behind this approach is that these anti-fouling practices are sufficient to reduce biofouling to an acceptable level.

The second approach, taken by entities such as New Zealand, and Western Australia, requires that vessels be clean upon arrival. This type of standard can be more difficult to evaluate, enforce, and comply with however, because the definition of “clean” may vary between different entities, and the required inspection protocols have not been fully developed. In some cases, ships may be required to take remedial action if they fall below the standard. Reflecting a growing trend to prohibit conventional (uncontained) in-water cleaning, such remedial action may include mandatory hull cleaning using capture/filter technology. This can be difficult and costly, and may be more appropriate in areas of high conservation value such as marine preserves.

Some entities use a risk-based management scheme, which recognizes that not all vessels pose the same level of threat from biofouling, therefore making more efficient use of limited resources. Risk-based management can be as simple as applying different standards for long-stay vs. short-stay vessels, or for international, inter-state, and within-state vessel movements. This approach can be used to focus current requirements, such as inspections on vessels determined to be high-risk, based on ship behavior, type, age of anti-fouling paint, etc., or to focus policy development on those vessel characteristics deemed to be the riskiest.

Hull cleaning approaches are shifting from managing the depletion of toxic compounds to more frequent cleaning of minor buildups, with the understanding that hull coatings and hull cleaning methods need to evolve accordingly. As a result, hull coating manufacturers are abandoning toxic antifouling formulations in favor of silicon based compounds that resist attachment, but require special care when cleaning, and epoxy coatings that are extremely durable and can withstand frequent cleaning. A number of new approaches have been tested, and others are under development or improvement. Due to the developing nature of regulatory initiatives as described above however, the progress of technology solutions is impeded by the slow pace of requirements. Without performance standards or other regulatory requirements, vendors are left to develop systems in a vacuum, targeting development to anticipate future commercial needs.

This study attempted to assess the cost of regulatory compliance associated with biofouling. While the cost of biofouling itself is significant, many difficulties exist with gathering accurate cost information. One of the difficulties is allocating costs between those attributed to regulatory requirements, versus those undertaken for normal business reasons, such as reducing fuel cost. In addition, many costs are associated with regulations that are proceeding through the administrative process, but not actually in place. For these reasons, and because industry may chose not to disclose cost data, estimated biofouling regulatory costs vary widely, suffer from a lack of comparable data, and are highly subjective.

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

µg/l	Micrograms per liter
ABG	Agency for the Regulation and Control of Biosecurity and Quarantine for Galapagos
AHCS	Advanced Hull Cleaning System
AHMV	Advanced Hull Maintenance Vehicle
ANS	Aquatic nuisance species
ANZECC	Australian and New Zealand Environment and Conservation Council
AROV	Autonomous remotely operated vehicle
BAT	Best available technology
BMP	Best management practices
CAD	Canadian dollars
CFR	Code of Federal Regulations
CG-OES	Coast Guard Office of Operational and Environmental Standards
COTP	Captain of the Port
CRMS	Craft risk management standard
CSLC	California State Lands Commission
DAFF	(Australian) Department of Agriculture, Fisheries & Forestry
DEQ	(Oregon) Department of Environmental Quality
DLNR	(Hawaii) Department of Land & Natural Resources
DOT	Department of Transportation
DPIF	(Australian) Department of Primary Industry & Fisheries
ECY	(Washington State) Department of Ecology
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FR	Fouling Rating
FRMA	(Australian) Fish Resource Management Act
FRMR	(Australian) Fish Resource Management Regulations
GMR	Galapagos Marine Reserve
GNPD	Galapagos National Park Directorate
gpm	Gallons per minute
HST™	Hull Surface Treatment
HullBUG	Hull Bio-Mimetic Underwater Grooming
IMO	International Maritime Organization
IMP	Introduced marine pest
LLC	Limited liability corporation
LNG	Liquid natural gas
MARAD	(U.S. Department of Transportation) Maritime Administration
MEPC	Marine Environmental Protection Committee
MGPS	Marine growth protection system
MPI	(New Zealand) Ministry for Primary Industries
N/A	Not applicable
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
NAVSEA	Naval Sea Systems Command

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

NIS	Non-indigenous invasive species
NISA	National Invasive Species Act
NMMA	National Marine Manufacturers Association
NOAA	National Oceanic & Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPRA	Notice of proposed regulatory action
NYCRR	New York Codes, Rules and Regulations
ONR	Office of Naval Research
OR	Oregon
PMNM	Papahānaumokuākea Marine National Monument
Psi	Pounds per square inch
RCW	Revised Code of Washington (State)
RDC	(USCG) Research and Development Center
ROV	Remotely operated vehicle
RWQCB	California Regional Water Quality Control Board
SCAMP	Submersible Cleaning and Maintenance Platform
SHI	Samsung Heavy Industries
SOLAS	(International Convention) for the Safety of Life at Sea
SP	Shaft Power
SPREP	Secretariat of the Pacific Regional Environmental Programme
STAIS	Shipping Transport of Aquatic Invasive Species (Task Force)
sVGP	Small Vessel General Permit
TBT	Tributyltin
TM	Trademark
U.S.	United States
UAE	United Arab Emirates
Um	Micrometer
USC	United States Code
USCG	United States Coast Guard
USD	U.S. dollars
USEPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service
UV	Ultraviolet
VGP	Vessel General Permit
WA	Western Australia
WANE(S)	Wildlife and Natural Environmental (Scotland)
WDFW	Washington Department of Fish & Wildlife
WET	Whale Shark Environmental Technologies
WMU	Waste management unit

1 INTRODUCTION

1.1 Background

Seagoing vessels contribute to aquatic biological invasions through the transport of non-indigenous aquatic nuisance species (ANS) in ballast water, and biofouling on submersed hull surfaces, appendages and in difficult to access “niche areas.” Although ballast water management practices have been mandated for several years by United States Coast Guard (USCG) regulations, biofouling has received little attention until recently, when ongoing research identified it as a major vector for the introduction of non-indigenous invasive species (NIS) (Reference 9).

Biofouling is the attachment of organisms to a surface in contact with water over time. Biofouling begins with the production of a microorganism-containing biofilm (slime layer) which occurs on a marine surface under the right conditions. Biofilm growth can progress to a point where it provides a foundation for macroorganisms such as seaweed or barnacles to attach. Some of these organisms may be invasive species, resulting in additional concerns.

Biofouling has been a longstanding problem for the maritime industry. One problem caused by biofilm growth is the eventual corrosion of the hull, leading to the ship's deterioration. Even before corrosion occurs, however, unattended organic growth can increase the roughness of the hull, increasing drag and fuel consumption. This has economic and environmental consequences, resulting in increased operating expenses and increased output of greenhouse gases. Increased fuel use due to biofouling is predicted to increase emissions of carbon dioxide and sulfur dioxide between 38 and 72 percent by 2020. The effect of biofouling on vessel power requirements is shown in Figure 1 (Reference 25). Even at the microbial biofilm level, prevention and remediation is a multi-billion dollar-a-year industry worldwide.

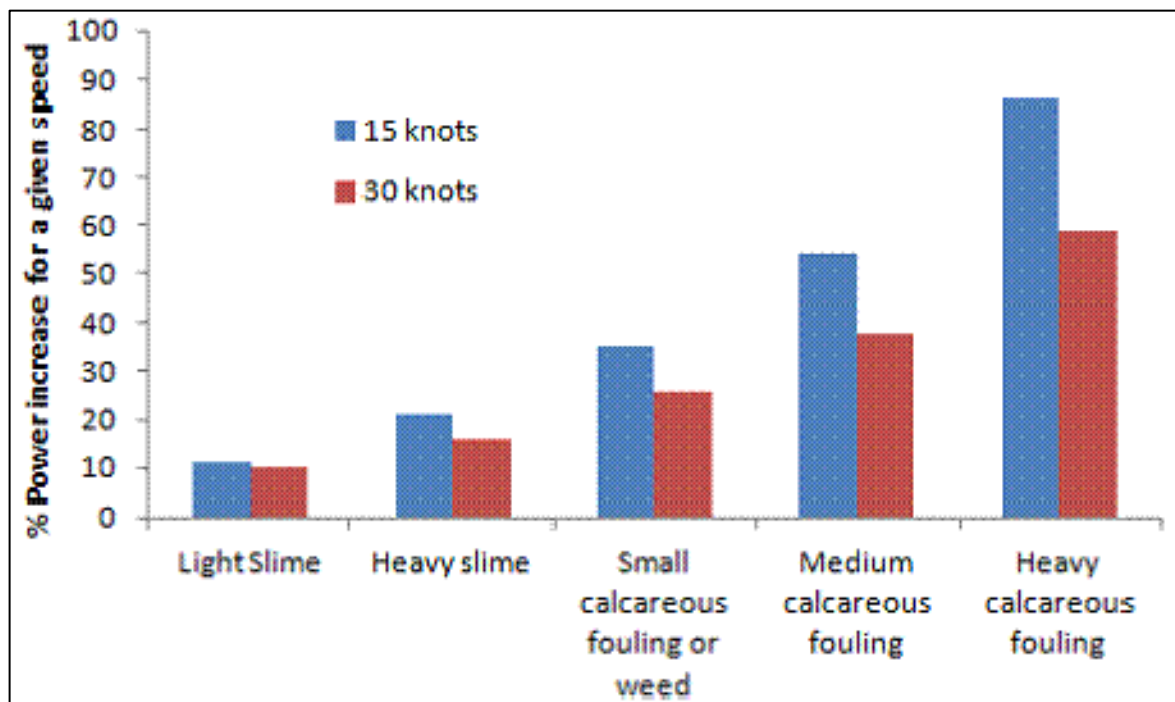


Figure 1. Effects of biofouling on vessel power requirements (Reference 25).



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The maritime industry has invested heavily in preventative technologies, such as anti-fouling coatings, however the most effective coatings contain toxins such as tributyltin (TBT) and copper. These compounds are known to concentrate in harbor sediment, leading to a 2008 worldwide ban on coatings containing TBT and efforts to mitigate or replace toxin-shedding hull coatings altogether. Despite a history of biofouling management and the important role shippers have played in reducing the amount of biofouling worldwide, biofouling-mediated invasions by NIS remain a concern. Governments and regional authorities are seeking new approaches to reduce the number and extent of the NIS invasions from vessels, and at the same time, minimize negative impacts on the marine environment.

Domestically, the USCG has authority to prevent the introduction and spread of ANS via means that include hull fouling. This authority is granted by the National Invasive Species Act of 1996 (NISA), which amended the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA). The USCG has exercised this authority by requiring the regular cleaning of vessel hulls, via regulations in 33 Code of Federal Regulations (CFR) 151.2035.

In 2009, the Coast Guard Office of Operational and Environmental Standards (CG-OES), formerly CG-523, funded an overview study on biofouling management (Reference 9). The study noted that shipboard biofouling impacts vessels in two ways; decreasing revenue and increasing expense. The cost associated with biofouling in the United States was estimated to be as much as \$120B per year, yet at the time, the U.S. did not have biofouling best management practices (BMP) guidelines for commercial or recreational vessels.

Increased visibility at international and Federal levels, coupled with evolving hull coating and hull cleaning technology created the desire for the USCG to update its knowledge of biofouling management practices. CG-OES called upon the USCG Research and Development Center (RDC) to perform market research and analysis, to update information essential for policy and regulation development concerning criteria/standards for biofouling effluent release to the environment, technology readiness, and overall effect on stakeholders. This tasking led to the current study and this report.

1.2 Scope

The purpose of the current study is to assess the state of technology, management practices, and regulatory initiatives within the U.S. and around the world to reduce harbor pollution and the introduction of ANS through vessel biofouling. The report focuses on in-water hull cleaning of commercial and recreation vessels, and addresses the following topics:

- Biofouling populations of concern.
- Current state of the commercial biofouling prevention market.
- Vessel locations subject to biofouling, including niche areas.
- Risks and impacts of biofouling on the environment, vessel structure, and vessel operation.
- Current state of scientific and technology research on biofouling prevention or management.
- Current state of regulatory actions among governments and regulating bodies that address biofouling prevention or management.
- Economic analysis of regulatory costs associated with biofouling regulations.

1.3 Research Methodology

The research team conducted internet and literature searches, and interviewed military, commercial, and civilian agencies. Topics included ship design, regulatory costs, hull cleaning and grooming, antifouling coatings, and emerging technologies to address biofouling mitigation. In addition, a team member attended the *Preventions 2014* conference sponsored by the California State Lands Commission (CSLC). The CSLC is one of the leading entities in the U.S. addressing vessel biofouling issues, having issued a Notice of Proposed Regulatory Action (NPR) (Reference 4) for public comment in 2011, regarding biofouling management standards. The conference featured a panel discussion on the future of in-water hull cleaning in California state waters, and provided an opportunity to interview state regulators, commercial dive operators and hull cleaning equipment vendors.

2 VESSEL STRUCTURES SUBJECT TO BIOFOULING

All submerged areas of the hull, including appendages and niche areas are subject to the accumulation of biofouling. As described earlier, biofouling begins quickly, with a light slime layer, and progresses over time to hard calcareous growths (Reference 5). In general, biofouling occurs more rapidly in niche areas, which are areas that are out of the normal flow of water along the outer hull surface when a vessel is underway. The relatively still water in these areas provides an environment where organisms can more easily attach to the hull, advancing the biofouling process. Niche areas typically exist either because the flow is shielded by an appendage, such as a shaft strut, or by hull design such as thruster tunnels or sea chests.

Niche areas are also problematic because they are difficult to access and clean. Most hull cleaning systems are designed to clean open, flat or broadly curved hull plate, rather than the partially closed or shielded niche areas. Cleaning the smooth sides and bottom of a hull through the process of physical scrubbing, heating or water jet blasting is a straightforward process, but niche areas that are not reachable by area cleaning machines require individual human attention and specialized tools. Tools used for cleaning niche areas include scrapers, water blast wands and hand-held rotary brushes. Ship design that minimizes sharp edges and hidden areas, and provides easy access to internal cavities can reduce the maintenance burden caused by hull biofouling. Common niche areas are:

- Sea chests and gratings;
- seawater inlet pipes and internal systems;
- cathodic protection anodes;
- sonar domes, transducers and velocity probes;
- drydocking support areas;
- propellers, shafts and struts;
- thrusters and thruster tunnels;
- retractable propulsion units;
- bilge keels and stabilizer fins;
- rudder, including hinges and stocks; and
- internal ships' spaces (e.g. chain lockers, bilges, bait wells).

The rate of biofouling growth is a function of factors that vary widely from vessel to vessel (Reference 5). These factors include:

- Season and water temperature. Warm water temperatures and long daylight periods are most conducive to biofouling growth.
- Underway speed. Rapid water flow over the hull surface makes it more difficult for biota to establish a foothold.
- Time underway versus time at anchor. Biofouling grows more rapidly in the relatively undisturbed water surrounding a ship at anchor or pierside.
- Age of hull paint. Ablative paints are most effective when freshly applied. Toxicity slowly declines as the toxicant is depleted through the ablatative process. Cleaning restores most of the effectiveness if the remaining layer is sufficiently thick.
- Location of ports visited. Climate, pollution and local hydrology (i.e., river versus harbor) are examples of local factors that affect the rate of biofouling accumulation.

3 RISKS AND ADVERSE EFFECTS OF BIOFOULING

Biofouling is destructive and expensive for maritime operations. In addition to potentially adverse effects on the environment, biofouling imposes both direct and indirect costs on the shipping industry. In simple terms, biofouling increases hull roughness, roughness increases drag, and drag increases fuel consumption. In addition, the costs of preventing biofouling are considerable; antifouling paint is expensive, and if improperly applied, multiple coats contribute to surface roughness that must eventually be stripped and reapplied at considerable expense. This section lists adverse effects attributed to biofouling.

3.1 Environmental Effects of Biofouling

- Vector for NIS. Numerous studies have demonstrated that invasive species can be transported from one region to another by attaching to hulls engaged in global commerce.
- Increased fossil fuel consumption/emissions. Biofouling increases hydrodynamic drag on hulls and propellers, requiring more fuel to push the vessel through the water. Increases in fuel consumption also increase emissions.
- Contamination. Biofouling indirectly causes chemical (copper, zinc) contamination of waters from ablatative antifouling paint. Ablation is the slow removal by wear of the bottom paint, a continuous process until the anti-fouling paint is depleted. Scrubbing the surface to remove growth accelerates ablation.

3.2 Effects of Biofouling on Vessel Structure

- Hull coating degradation. Organisms can damage coatings by attaching themselves to the surface. Removing these organisms through hull cleaning hastens the depletion of ablatative paint.
- Hull damage/corrosion. Degraded hull coatings lose their protective properties, exposing bare metal to salt water.
- Increased engine stress. Increased roughness on the hull surface, increasing drag, which in turn requires more power to maintain a given speed, adding to engine stress.
- Seawater system degradation/damage. Biofouling can clog and restrict raw cooling water flow to vital systems. This can result in increased maintenance and shortened service life of these systems, and to the extent that their performance is compromised, the vital systems they serve may also be effected.

3.3 Operational Costs of Biofouling

- Increased fuel costs. Fuel costs are a major component of vessel operating expense, hence increases in fuel consumption have serious economic impacts.
- Speed/time disadvantages. Decreased speed results in longer voyages for commercial vessels and may put military vessels at a tactical disadvantage.
- Hydroacoustic noise. “Dirty hulls” create noise that degrades the performance of sonar on military ships and scientific equipment on oceanic research vessels.
- More crew underway days. Decreased speed means longer voyages between ports, increasing crew costs relative to the distance traveled.
- Increased use of drydocking. Periodic hull surveys can be conducted in-water; however, tightening regulations are pushing ship owners to perform hull cleaning in drydock, thus incurring additional costs. In addition, frequent cleaning shortens the service life of most antifouling coatings.
- Hull/propeller grooming expenses. Regardless of the anti-fouling system employed, biofouling accumulates and must be removed periodically to maintain propeller efficiency and hence optimum ship performance.

4 BIOFOULING POPULATIONS OF CONCERN

This section addresses the populations of ships and boats subject to biofouling. This information cannot be obtained from one source, but must be gleaned from several references. Table 1 through Table 3 provide different presentations for this information, each supported by a different data source, and generated with a different focus or intent. Each table presents a component of the worldwide population of vessels that could potentially come under USCG jurisdiction for biofouling management purposes.

Table 1. Worldwide population of merchant vessels (2013).

Ship Type	Small ⁽¹⁾		Medium ⁽²⁾		Large ⁽³⁾		Very Large ⁽⁴⁾		Total	
General Cargo Ships	4,330	14.6%	11,670	31.8%	201	1.9%			16,201	19.9%
Specialized Cargo Ships	8	0.0%	201	0.5%	52	0.5%	2	0.0%	263	0.3%
Container Ships	16	0.1%	2,256	6.1%	1,584	15.4%	1,038	21.4%	4,894	6.0%
Ro-Ro Cargo Ships	33	0.1%	656	1.8%	605	5.9%	161	3.3%	1,455	1.8%
Bulk Carriers	318	1.1%	3,514	9.6%	4,981	48.3%	1,544	31.8%	10,357	12.7%
Oil and Chemical Tankers	1,772	6.0%	6,440	17.5%	2,301	22.3%	1,483	30.5%	11,996	14.7%
Gas Tankers	40	0.1%	1,034	2.8%	197	1.9%	346	7.1%	1,617	2.0%
Other Tankers	284	1.0%	475	1.3%	5	0.0%			764	0.9%
Passenger Ships	3,568	12.0%	2,476	6.7%	273	2.6%	146	3.0%	6,463	7.9%
Offshore Vessels	2,367	8.0%	4,847	13.2%	94	0.9%	132	2.7%	7,440	9.1%
Service Ships	2,325	7.8%	2,259	6.2%	24	0.2%	5	0.1%	4,613	5.7%
Tugs	14,621	49.3%	900	2.5%					15,521	19.0%
Total	29,682	100%	36,728	100%	10,317	100%	4,857	100%	81,584	100%

(1) GT<500 - (2) 500≤GT<25,000 - (3) 25,000≤GT<60,000 - (4) GT≥60,000

Source: European Maritime Safety Agency (emsa.europa.eu).

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Table 2. Number and size of U.S. flag merchant fleet and its share of the world fleet (2009-2012) (ocean-going self-propelled, cargo-carrying vessels of 1,000 gross tons and above).

Vessel Categories	2009	2010	2011	2012
World fleet	34,966	33,586	34,987	36,000
U.S. fleet, total	217	221	214	198
Freighters, total	137	138	138	139
General Cargo	19	18	20	22
Container	76	80	79	80
Partial containerships	N	N	N	N
Ro-Ro	42	40	39	37
Tankers, total	59	62	60	49
Petroleum/chemical ships	59	62	60	49
Liquefied petroleum/natural gas ships	N	N	N	N
Integrated tug and barge, total	9	9	4	2
Dry Bulk, total	12	12	12	8

NOTES

1. N = no data.
2. Data excludes non-merchant type and/or U.S. Navy-owned vessels currently in the National Defense Reserve Fleet.
3. Data excludes ships operating exclusively on the Great Lakes and inland waterways, and special types such as: channel ships, icebreakers, cable ships, and merchant ships owned by military forces.
4. Vessel categories are defined as:
General Cargo: General Cargo Carriers, Partial Containerships, Refrigerated Ships.
Container: Fully Cellular Containerships.
Ro-Ro: Ro-Ro Vessels, Ro-Ro/Containerships, Vehicle Carriers.
Tankers: Petroleum Tankers, Chemical Carriers, Liquid Natural Gas (LNG) Carriers, LNG/LPG Carriers, LPG Carriers.
Dry Bulk: Bulk Vessels, Bulk Containerships, Cement Carriers, Wood Chip Carriers, Ore/Bulk/Oil Carriers, Bulk/Oil Carriers.

Source: U.S. Department of Transportation Bureau of Transportation Statistics

Table 3. U.S. population of USCG registered pleasure craft (2012).

Boat Class	Number Registered
Power Boats	9,926,221
Personal Watercraft	1,268,624
Sail Boats	249,803
Other Boats	737,509
Total	12,182,157

Source: National Marine Manufacturers Association (NMMA)

The U.S. Environmental Protection Agency (EPA) is proposing the Small Vessel General Permit (sVGP) for discharges incidental to the normal operation of non-military, non-recreational vessels less than 79 feet (Reference 22). Table 4 summarizes the U.S. vessels that would need to have a Biofouling Management Plan when the sVGP was scheduled to be implemented beginning 12/19/2014.

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Table 4. Vessel counts for BMPs applicable to vessel hull maintenance.

Vessel Class	Total Vessel Count (Lower Bound Estimate)	Total Vessel Count (Upper Bound Estimate)	Trailered Vessel Count (Lower Bound Estimate)	Trailered Vessel Count (Upper Bound Estimate)
Commercial Fishing Services	67,178	67,713	7,626	7,687
Freight Barges	4,288	8,016	53	99
Freight Ships	579	768	34	45
Passenger Vessels	18,660	20,953	1,761	1,978
Public Vessels, Unclassified	67	622	10	94
Tank Barges	287	923	39	126
Tank Ships	49	179	2	7
Utility Vessels	8,876	11,034	767	954
Unspecified	15,012	27,375	5,859	10,685
TOTAL	114,996	137,583	16,152	21,674

Source: U.S. Environmental Protection Agency (EPA)

Table 5 contains a summary of U.S. port visits by foreign and U.S. flagged vessels between 2006 and 2011, indicating an average of 60,000 port calls per year.

Table 5. Merchant vessel calls at U.S. Ports, 2006-2011 (foreign and domestic flagged).

Type	2006	2007	2008	2009	2010	2011
Product Tanker	12,746	12,671	12,182	11,413	12,537	14,827
Crude Tanker	7,645	8,028	7,914	7,578	8,295	8,985
Container	19,587	19,859	18,729	18,199	19,521	22,089
Dry Bulk	11,579	10,081	9,513	7,884	9,227	10,947
Ro-Ro	6,315	6,074	5,962	4,947	5,842	6,182
Gas	879	824	698	659	738	857
Combo	319	222	169	127	158	120
General	3,983	3,844	3,584	3,274	3,553	4,029
All Types	63,053	61,603	58,751	54,081	59,871	68,036

Source: US Department of Transportation Maritime Administration (MARAD)

5 CURRENT BIOFOULING MANAGEMENT PRACTICES

Biofouling management practices are broadly categorized as proactive (preventative) and reactive (removal). Preventative measures include hull coatings that present bio-toxic surfaces to the immediate water layer, silicon based formulas that resist attachment of organisms but are susceptible to damage from hull cleaning, or extremely hard and/or smooth coatings that do not resist attachment as well as silicon coatings, but are highly resistant to damage from hull cleaning. While this report concentrates on hull cleaning, it is worth noting that hull coating and hull cleaning technologies combine to form complete biofouling management strategies. Developments in one industry, (e.g., silicon based coatings, which can be more sensitive to abrasion) affect developments in the other (e.g., non-contact hull “scrubbers” [see section 5.2.3.4]).

This section presents biofouling management approaches that are commercially available or under development, by private industry, government, or private/public partnerships. In all cases, the project team presents the capabilities of systems as expressed by the vendor, manufacturer, or government sponsor, as testing these aspects was beyond the scope of the current effort. In addition, the quantity and quality of information relating to design

and performance of systems varied greatly. In anticipation of an intensely competitive future market for environmentally friendly biofouling mitigation equipment, the parties involved were guarded in providing information.

5.1 Biofouling Prevention

Until recently, preventative measures have consisted mainly of hull coatings containing toxins such as copper and/or zinc to inhibit marine growth. Hydrolysis and mechanical action from water flow causes the surface to ablate (wear away), shedding some growth, and continually exposing a fresh layer of toxicant. The main disadvantage of ablative anti-fouling paint is that the toxin can accumulate in harbors and near shore in areas of concentrated vessel traffic (Reference 5). In-water hull cleaning using conventional hull scrubbers exacerbates this problem by releasing the surface layer into the water column, and shortening the life of the coating.

In response to the issues raised by the use of hazardous ingredients, hull coatings are evolving towards silicon-based formulas that discourage initial attachment of marine growth, and shed growth more readily when underway. At the same time, manufacturers of hull cleaning equipment are developing hull scrubbers that employ less abrasive brushes or water jets, as silicon-based surfaces are softer and more fragile than conventional anti-fouling paints (Reference 3). A significant trade-off when using non-toxic paint in conjunction with less severe cleaning methods is that biofouling accumulates more rapidly, especially on slower moving ships, and, while it is easier to remove, it must be removed more frequently.

5.1.1 Biofouling Prevention; Current/Near Future Approaches

Hydrex[®] Group of Antwerp, Belgium has developed a non-toxic glass flake vinylester resin based hull coating called Ecospeed[®]. According to the manufacturer, Ecospeed is applied in two coats versus the four to five coats required for conventional antifouling paint, and the resulting coating remains effective the life of the ship. Hydrex claims the coating is easy to clean and virtually impervious to damage from hull cleaning; hence it can be cleaned more frequently. According to Hydrex[®], each cleaning improves surface smoothness, resulting in gradually increasing fuel economy as the ship ages (Reference 13). Due primarily to their non-toxic makeup, Ecospeed[®] and other hard non-toxic hull coatings, along with frequent cleaning, are considered a best available technology (BAT) to prevent biofouling (Reference 29).

For pleasure boats, new developments such as the Armoredhull[™] inflatable hull enclosure (Figure 2) and the Barnacle Barrier[™] floating drydock (Figure 3) prevent hull fouling by isolating the hull from the surrounding water when the vessels are in port.



Figure 2. Armoredhull[™] inflatable hull enclosure.



Figure 3. Barnacle Barrier™ floating drydock.

Using a different approach, the Australian firm CleanABoat® has developed an ultrasonic system that they claim will repel marine growth by using the hull as a sounding board for low power high frequency waves that destroy live cells. The company estimates the installation costs at \$100AU per linear foot (Reference 11).

Electrolyzation of seawater has proven successful in protecting sea chests, traditionally a difficult niche area to keep free of biofouling. Electrically charged copper and aluminum anodes within the sea chest produce chlorine compounds that collect in the sea chest and are toxic to organisms that would otherwise attach themselves to the surfaces within the cavity (Reference 10).

5.1.2 Biofouling Prevention; Exploratory Research

The U.S. Navy's Office of Naval Research (ONR) is involved in two research programs to develop advanced solutions to biofouling. The first initiative, a collaboration with the University of Florida, is investigating Sharklet™ coating, which incorporates micro-patterned surface texture and antimicrobial properties to repel organisms. The second effort, involving researchers at the University of Washington, is exploring Zwitterionic (mixed charge, alternating -/+) compounds, which prohibit proteins and cells from binding to the hull (Reference 16).

5.2 Biofouling Removal

Since the ideal antifouling coating has yet to be developed, vessel owner/operators must rely on various methods of physical removal of biota to maintain acceptably clean hull surfaces. Due to the high cost of drydocking in terms of dollar outlays and schedule down time, in-water hull cleaning is the preferred option from an operational standpoint. As noted elsewhere in this report, environmental issues are driving antifouling technology away from highly effective toxin-containing coatings toward more benign coatings that must be cleaned more often, but require gentle cleaning processes. At the same time, more ports, particularly along the U.S. West Coast, are prohibiting in-water hull cleaning of toxicant bearing hulls to avoid heavy metal contamination. As a result, commercial vessel and dive operators may need to choose between hull cleaning offshore (outside the jurisdiction of the applicable authorities), or costly drydocking. Furthermore, except as noted in section 5.2.2.2, the absence of standards for acceptable levels of metal and biological contamination in hull cleaning effluent, prevents equipment vendors from designing and building systems that can be "certified" for in-port, in-water hull cleaning. In anticipation of ever more restrictive laws governing the release of biotoxins and potentially invasive aquatic species, government and commercial entities are working on developing hull cleaning systems that are compatible with hard and soft coatings, and capture and filter the effluent as it is removed from the hull.

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The below sections summarize biofouling removal practices currently in use by the U.S. Government and commercial industry, and describe some promising new biofouling removal systems. Commercial systems are described to the level of detail provided by their respective manufacturers; included are some systems for which the manufacturers declined to provide details for this report.

5.2.1 Biofouling Removal: U.S. Current Practices

Commercial dive companies are currently cleaning the hulls of large vessels offshore on the West Coast and Gulf Coast. Local environmental regulations limit commercial hull cleaning within copper impaired harbors in California and Washington. An official with the San Francisco office of the California Regional Water Quality Control Board (RWQCB) explained that the prohibition against hull cleaning in San Francisco Bay was occasionally violated by dive companies. The official stated that the companies believed either they would not be caught, or felt the penalty for a violation was less than the cost savings from working offshore.

The U.S. Navy routinely performs pierside in-water hull cleaning at their facilities along the Gulf Coast. Commercial divers in that region, however, prefer the improved visibility found in open water for hull cleaning operations, despite the need for increased logistical support (workboats, barges, etc.). Good visibility contributes to diver safety, makes it easier to navigate over the hull surfaces and avoid obstructions, and ensure no areas are overlooked.

As a general rule, major U.S. shipyards avoid in-water hull cleaning. Shipyards consulted on the Atlantic, Pacific and Gulf coasts performed biofouling removal in conjunction with drydocking required for other major maintenance or repair reasons. Effluent is contained by storm water systems and prepared for discharge into local wastewater facilities by captive wastewater treatment plants that operate in accordance with local regulations.

In-water hull cleaning by commercial vessels is prohibited within the Port of Virginia; however due to short turnaround times for commercial vessels and strong currents offshore, most commercial vessel operators schedule hull cleaning to avoid this region. Several commercial dive operators stated that, due to environmental regulations, costs, and the necessity for minimum in-port times, commercial ship owners simply avoid hull cleaning in any U.S. port.

The U.S. Navy performs in-water hull cleaning at all major stateside bases except in Washington State. The Navy avoids Washington's stricter regulations as part of their "good neighbor" policy with the caveat that they will perform in-water hull cleaning there in cases of operational necessity. Regarding NIS, the Navy's approach is to assume that the bulk of biofouling occurs during extended homeport periods, and there is no harm in returning those organisms to their harbor of origin. In all cases, current best practices dictate that ablative antifouling coatings be cleaned using the least aggressive means available to minimize shedding toxic compounds.

Many localities and municipalities, beginning with the state of California and spreading nationwide, have taken a proactive approach to harbor pollution from NIS and copper fouling through the Clean Marinas program (see Reference 12). The nationwide initiative is a partnership between private marina owners, government marina operators, and yacht clubs. Clean Marinas was developed to provide clean facilities to the boating community and protect waterways from pollution. The program provides boaters and marinas with the following recommendations:

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5.2.1.1 Marina and Yacht Club BMP

1. Use nontoxic and legal hull paints to reduce the possibility of contamination when performing hull cleaning.
2. Properly functioning anti-fouling paint will repel all hard growth and requires only occasional light wiping with a soft cloth to remove slime. Aggressive cleaning of anti-fouling paint using tools such as scrubbing pads and powered rotary brushes will shorten the effective life of the paint significantly, and should never be used. Aggressive cleaning of this nature increases the amount of copper entering the water column and sediment. The boat should be hauled and recoated with fresh anti-fouling paint before this style of cleaning is ever required.
3. Use soft cloth or fleece mitt only. Avoid scrapers (metal/plastic/wood), abrasives (sandpaper/cleanser/soft scrub), Scotchbrite®/3M® pads, and powered rotary brushes.

5.2.1.2 Boater BMP

1. Ensure hull paint is properly applied and maintained to protect the hull from fouling organisms and thus improve your boat's performance.
2. Wait 90 days after applying new bottom paint before underwater cleaning.
3. Schedule regular hull cleaning and maintenance to reduce the build-up of hard marine growth and eliminate the need for hard scrubbing.
4. Schedule regular gentle cleans to increase the effectiveness of the antifouling hull paint and extend its useful life.
5. Use, or ask your hull cleaning service to use, Underwater Hull Cleaners' BMP. Ask your service to monitor the work of the divers that they hire or subcontract to ensure they are using BMPs.
6. Repair paint bonding problems at haul-out to avoid further chipping and flaking of paint in the water.
7. Use, or ask your diver to use, non-abrasive scrubbing agents, soft sponges or pieces of carpet to reduce the sloughing of paint and debris.
8. Employ boat hull cleaning companies and individuals that practice environmentally friendly methods.
9. Encourage divers to use different types of pads when necessary to properly maintain a vessel's bottom paint (example: In many cases surfaces close to the waterline are more susceptible to higher growth rates therefore you need to use different pads in order to properly remove marine growth and corrosion. Likewise, a softer pad can be used for the rest of the vessel to maximize hull performance and optimize the lifespan of the paint.)
10. Notify hull cleaning service as to what type of bottom paint was used and when the bottom was last painted.

Similar efforts are being formed regionally within the U.S., by organizations such as the five-state Gulf of Mexico Alliance Clean & Resilient Marina Initiative and the Great Lakes Clean Marina Network.

5.2.2 Biofouling Removal: Government Efforts

5.2.2.1 U.S. Navy

At least two government agencies are developing hull cleaning systems that capture and filter discharge water. The U.S. Navy's Advanced Hull Cleaning System (AHCS) and Automated Hull Maintenance Vehicle (AHMV) comprise a remotely controlled (diverless), automated Submersible Cleaning and Maintenance Platform (SCAMP), or brush cart, that vacuums debris and toxins as it cleans and transfers the effluent to a pierside waste management unit (WMU). Although designed primarily to capture copper particles, the system filters out all solid debris greater than 20 microns. The resulting pollutant concentrations in the discharged water are <5mg/l of biota and <1 mg/l of copper (Reference 7). The main

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drawback to the AHCS/AHNV is cost; its employment raises the cost of cleaning a typical 300 meter naval vessel by a factor of five. The Navy system is currently being operated under the Naval Sea Systems Command (NAVSEA) hull cleaning contract as a prototype test bed in Pearl Harbor, Hawaii.

5.2.2.2 U.S. Department of Transportation (DOT) Maritime Administration (MARAD)

A second capture/filter system was developed and tested in San Francisco Bay by the U.S. DOT Maritime Administration (MARAD) in collaboration with Terraphase Engineering Inc. The purpose of the initiative was to establish a BAT to control the discharge of metals into California state waters. The MARAD system comprises a conventional diver-guided brush cart, modified with a rubber skirt to trap debris under the cart body and a suction hose to vacuum the debris to a pierside storage and filtration system (Figure 4). The filtration system was built from commercially available components and included mesh filters to remove solids and an organic-clay (modified zeolite) filter to remove dissolved metals.

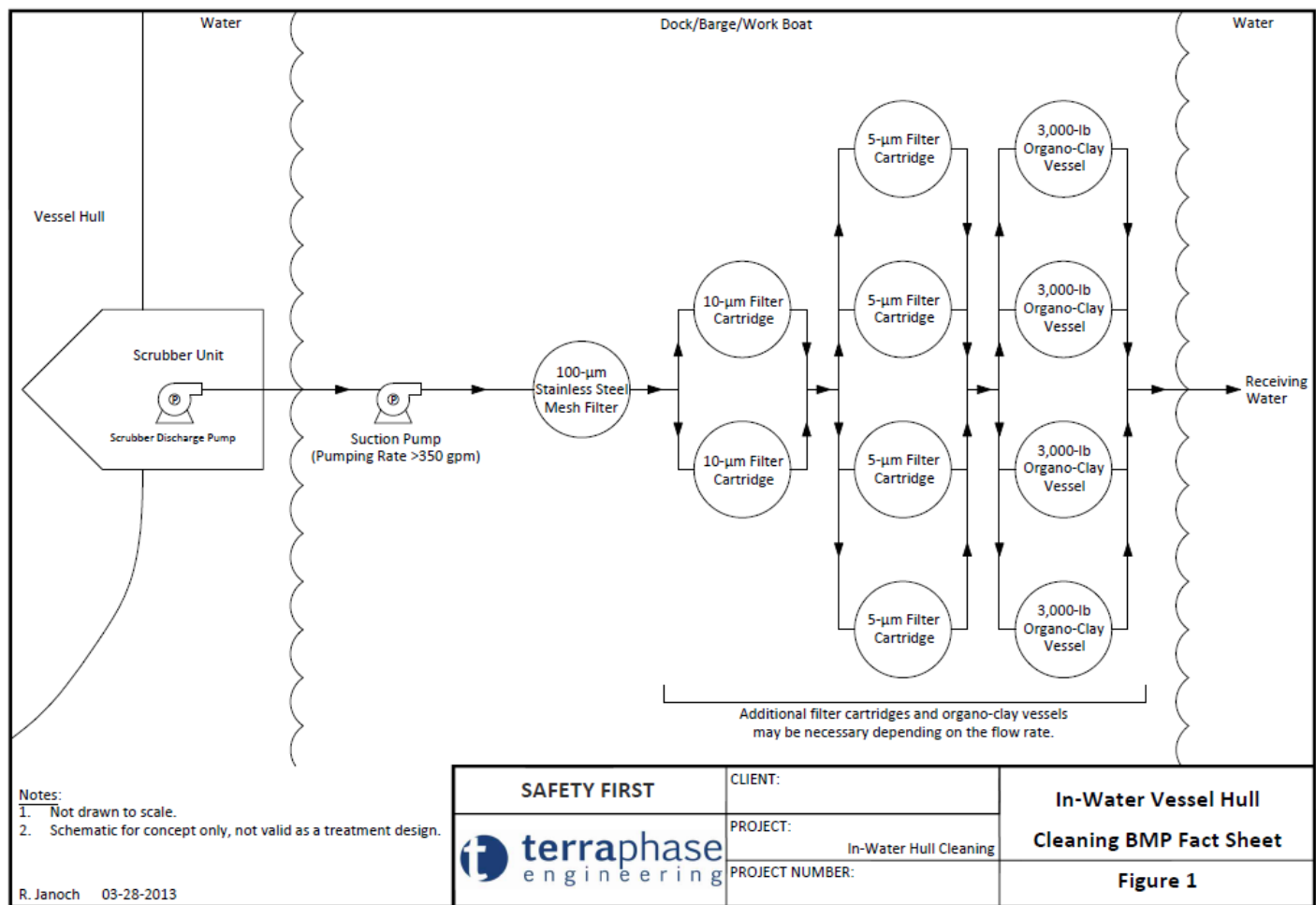


Figure 4. MARAD experimental capture and filter prototype hull cleaning system.



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Although the MARAD system's effluent concentrations of approximately 100 µg/l (micrograms per liter) for copper and 600 µg/l for zinc did not meet the standards of the San Francisco Bay RWQCB, the Board allows a mixing zone (dilution credit) to be incorporated into the cleaning protocol. This approach allows the waste metals to be discharged at a concentration above the acceptable standard, if a sufficient volume of water is available to receive and further dilute the effluent. Based on test results from the MARAD experiments, the San Francisco Bay RWQB proposed a BAT for in-water hull cleaning based on:

- The use of a scrubber unit with non-metal brushes, a rubber seal against the vessel hull, pressure differential monitoring between the inside of the scrubber unit and the ambient water with a minimum differential pressure of 3 psi, and collection of the process water at a minimum of 350 gallons per minute (gpm).
- The stipulation that only the soft growth be removed in order to minimize the disturbance of the paint coating.
- The filtering of process water in a treatment system through a maximum of a 5 µm filter prior to discharge (larger filters can be used earlier in the treatment train to remove larger particles in steps).
- The use of a treatment system to reduce dissolved copper concentrations to approximately 100 µg/l.
- The use of a treatment system to reduce dissolved zinc concentrations to approximately 600 µg/l.
- In conjunction with the above BAT, a discharge permit from the RWQCB.

A complete description of the MARAD system and test can be found in Reference 27. To date, at least one Monterey Bay dive company, Innermost Containment Systems L.L.C. has developed and is commercially employing its own equivalent capture/filter system (see section 5.2.3.1).

5.2.3 Biofouling Removal: Private Industry Efforts

There are currently several commercial companies working to develop hull cleaning systems to counter the NIS threat and/or mitigate heavy metal pollution. Technical specifications are provided where available; some vendors were reluctant to release details due to pending patents, and to protect other business sensitive information.

5.2.3.1 Innermost Containment Systems Limited Liability Corporation (LLC)

The Innermost Containment system employs a filter system patterned after the DOT-MARAD system described in section 5.2.2.2. The main difference lies in the effluent capture system that comprises a floating gated framework that surrounds the vessel and supports a rubber envelope. The rubber envelope completely isolates the vessel and effluent from the surrounding water during the cleaning process. Once isolated, the method of cleaning is left to the discretion of the diver performing it (see Figure 5). Prior to releasing the vessel from the envelope, the captured contaminated water can be recirculated through the filter system until the contamination reaches an acceptable level, or vacuumed out, filtered and returned to the harbor. If the second option is chosen, the rubber envelope comes to the surface and collapses against the hull so that it can be completely emptied before being opened to allow surrounding water to flow in and the vessel to exit (see Figure 6). Although both figures depict a small sailboat, the company claims the system can be scaled to contain large commercial ships as well (Reference 14). Innermost Containment Systems Limited Liability Corporation (LLC) is currently operating commercially as a BAT under a letter of approval from the Monterey Bay RWQCB.



Figure 5. Vessel undergoing hull cleaning within Innermost Containment Systems barrier.



Figure 6. Hull cleaning effluent being vacuumed from within an Innermost Containment Systems barrier.

5.2.3.2 *Whale Shark Environmental Technologies (WET) (Canada)*

The WET system is a brush cart capture/filter system that is advertised as being capable of filtering particles larger than 20 microns. According to WhaleShark, this filtering capability removes 95-percent of organic material and 90-percent of metals from effluent at a flow rate of 120 gpm. In 2011, Port Metro Vancouver approved WET's capture technology for hull cleaning in the Port of Vancouver (Reference 20). The WET unit is a prototype (Figure 7), but the manufacturer expected the unit to be commercially available by the end of March 2015 at a cost of \$500,000 Canadian dollars (CAD). WET estimates that use of the WET unit adds approximately \$7,000 CAD to the cost of cleaning a 300-meter ship using conventional methods.

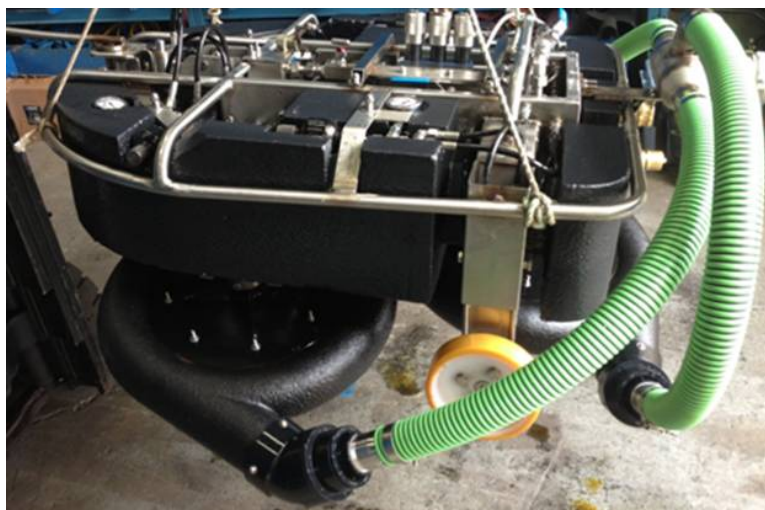


Figure 7. Prototype WET brush cart with capture technology.

5.2.3.3 GAC EnvironHull HullWiper™ (United Arab Emirates (UAE))

The GAC EnvironHull HullWiper™ (Figure 8) is an remotely controlled (diverless) cart that uses water blast jets to remove light to medium biofouling without damaging hull coatings (Reference 18).

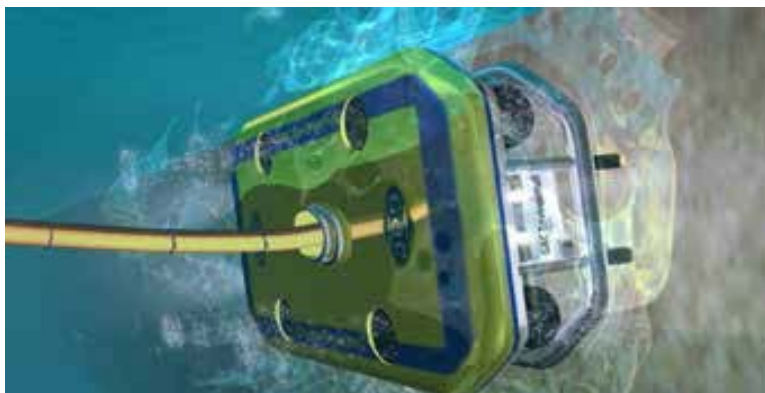


Figure 8. GAC's HullWiper™ autonomous hull cleaner.

The HullWiper™ system incorporates a filter system to remove biological material and metals from the effluent generated by its water blast. GAC EnvironHull claims cost savings over brush cart systems, partly due to the HullWiper's ability to clean up to 2000 square meters/hour and partly due to its gentle treatment of hull coatings. The HullWiper has been approved to perform in-water hull cleanings in all Norwegian ports and in the port of Jebel Ali in the UAE. GAC provided cost figures shown in Table 6.

Table 6. Estimated cost advantage of water blast versus brush cart for hull cleaning.

Cost	ROV* with Water Jets	Diver with Brush Cart
Actual cleaning cost	\$3.50/meter**	\$1.20/meter
Actual antifouling damage	\$0.00/meter	\$6.00/meter
Total	\$3.50/meter	\$7.20/meter

* Remotely operated vehicle (ROV)

** Costs are provided per square meter

5.2.3.4 *FranMarine Envirocart™ (Australia)*

The FranMarine Envirocart™ (Figure 9) is another advanced capture/filter system that employs a diver-guided cart that can be equipped either with conventional brushes or with rotating blades that remove fouling from the hull while using a “shaving” action as well as a powerful trailing vortex without actually contacting the surface. The scrubber unit is hinged so that it can follow curved hull surfaces. The Envirocart™ incorporates a filtration system with a 50-micron primary filter, and a series of 5-micron filters, followed by an ultraviolet (UV) reactor to sterilize the effluent.



Photo courtesy of GRD FranMarine

Figure 9. FranMarine's EnviroCart™.

In trials, the Envirocart™ has demonstrated its ability to remove, capture, and filter out bio-particles greater than 50 microns, with no damage to the antifouling paint. In addition, chemical contamination is reduced to levels that meet Australian and New Zealand water quality guidelines for discharge directly into adjacent waters (Reference 2).

5.2.3.5 *Limpieza Purotecnica S. A. Cavi-Jet™ (Spain)*

The Cavi-Jet™ (Figure 10) is a biofouling removal system that employs a stream of microscopic steam/gas bubbles that explode when striking a hard surface. The shock waves generated by the exploding bubbles disrupt rust, flaking paint and organic material. The company claims multiple operating modes are available to suit the surface being cleaned and the level of infestation. The manufacturer declined to participate in this survey, therefore information was obtained from public sources.



Figure 10. Limpieza Purotecnica S. A. Cavi-Jet™ cleaning head.

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A diver operation company that was interviewed for this report stated that they used a similar “cavitator” system with satisfactory results, but its slower coverage speed compared to their triple brush scrubber cart limited its use to vessels less than 100 feet in length.

5.2.3.6 Commercial Diving Services Hull Surface Treatment (HST™) (Australia)

The HST™ employs heated seawater to kill biofouling organisms without affecting the underlying hull coating. The HST™ comprises a tender mounted boiler that heats water up to 72 degrees C and pipes it to a thermal applicator. The thermal applicator is a surface controlled cart that rides on rollers while being held against the hull by rare earth magnets. A rubber skirt traps the hot water against the hull as the thermal applicator is moved in a grid pattern along the vertical sections of the ship’s hull. Following treatment, the dead organisms are washed off by hydrostatic forces when the ship gets underway. The HST™ capability is limited to primary (light to moderate) biofouling, and currently works only on vertical or near vertical surfaces. Its use is also limited to ferrous hulls due to its magnetic “clinging” approach. The thermal applicator is controlled from a tender or from the ship being cleaned; however, diver intervention is required for most niche areas (Figure 11).



Figure 11. Commercial Dive Services’ HST™ tender and thermal applicator (Reference 19).

5.2.3.7 Small Craft/Pleasure Craft - Aeffe Srl KeelCrab™ (Italy)

Aeffe Srl of Italy (Reference 15) has developed a miniaturized hull scrubber intended for the small craft and pleasure craft market. The KeelCrab™ is a portable unit that is controlled from pierside or from an alongside vessel (Figure 12). The user guides the scrubber head by remote control, using an onboard video camera to navigate the vessel's hull. Since the unit is "driven" manually from topside using the video camera, good water clarity is expected to be a required factor for its successful use.



Photo courtesy of Aeffe Srl

Figure 12. Aeffe Srl's KeelCrab miniature hull scrubber with remote control unit.

5.2.3.8 Small Craft/Pleasure Craft - Waveblade™ and Powershark™ - Waveblade Technologies (Scotland)

Waveblade™ Technologies (Reference 17) has developed hand-held, electrically powered hull scrapers for small craft that employ variously shaped vibrating blades to remove soft and hard growth. The company offers 12-volt corded (Figure 13) and battery powered versions.



Photo courtesy Marine Control S.L.

Figure 13. Waveblade™ handheld vibrating hull scraper.

5.2.4 Autonomous Remotely Operated Vehicles (AROV)

Recent advances in ROVs that are capable of navigating along a ship's hull autonomously are indirectly contributing to safer, more flexible hull cleaning operations. "Autonomous" is a term that may be used in slightly different ways in describing systems. The key element with the two systems described below is that they are operated without the requirement for a diver or a topside "hands on" operator. These systems can be combined with hull cleaning apparatus to create diverless systems that can operate safely and with minimal support at night or in low visibility conditions.

5.2.4.1 Samsung Heavy Industries (Korea)

South Korea's Samsung Heavy Industries (SHI) is developing an AROV adapted to cleaning the hulls of new liquid natural gas (LNG) ships prior to customer delivery (Figure 14). Onboard sensors will navigate by maintaining a set depth and direction, and steering around obstacles that protrude from the hull. The organic matter will be collected and filtered.

The SHI system specifically targets the LNG shipbuilding industry and is limited to removing the light fouling found on LNG tanker hulls that typically sit at dockside or at anchor for six to eight months during final construction (Reference 24).

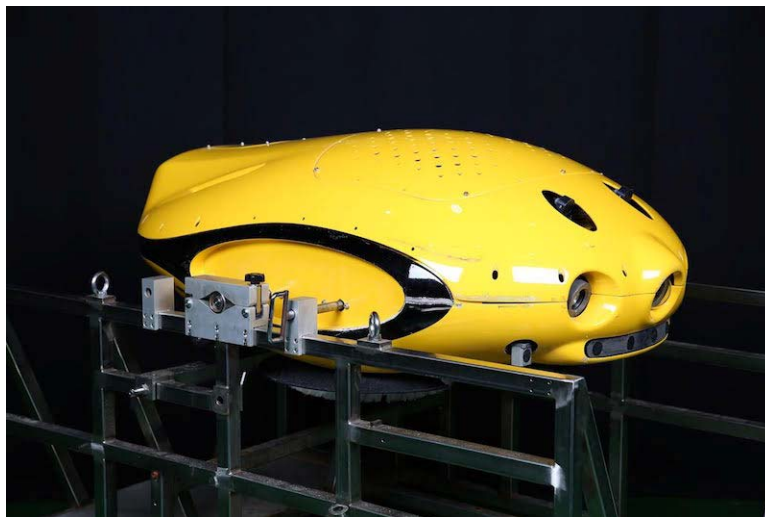


Figure 14. Samsung Heavy Industries hull cleaning robot.

5.2.4.2 U.S. Navy Robotic Hull Bio-Mimetic Underwater Grooming (Hull BUG) System

The Hull BUG (Figure 15) uses four wheels and negative pressure to hold it against the hull. Its unique capabilities lie in sensors that provide obstacle avoidance, path planning, and navigation. It can also differentiate between fouled and groomed surfaces to assist it in maintaining a systematic pattern. The Hull BUG is being developed by Naval Surface Warfare Center, Carderock, and expecting full-scale trials in 2015. In addition to performing hull surveys, the Hull BUG is expected to eventually be equipped to perform hull grooming.



Figure 15. Hull BUG AROV.

6 REGULATORY ACTIONS

It is clear that biological invasions are problematic and that ship biofouling is a major vector for marine invasions. While shippers and the maritime industry invest heavily in preventative technologies (such as anti-fouling coatings), new invasions are being recorded throughout the U.S. and the world. As a result, governments and regional authorities are seeking additional ways to reduce the number of marine invasions that occur from this vector.

This section outlines biofouling management regulations that are in effect or being developed for near-future implementation. At the international level, the number of governments taking action to regulate biofouling management is relatively small. As noted earlier, information on key regulations and pending legislation was drawn from web searches and interviews via phone and email to provide an up-to-date review of biofouling policy around the world. Information on policy in foreign countries was obtained directly from governing legislative documents or from academic or policy professionals in those countries. For policy information at the state level in the U.S., relevant governmental departments, including those charged with managing marine resources, boating, and environmental quality were consulted. The sections below provide synopses of biofouling regulations for each jurisdiction, citing the appropriate policy documents.

Some states, notably CA, Oregon (OR), WA, and HI have indicated the desire to arrive at similar regulatory schemes, with one state typically taking the lead. While this intention may eventually lead to more uniform requirements over larger areas, other factors, such as politics and economics may weaken this approach. In addition, there can be a significant difference between regulatory initiative, which is reported in this study, and enforcement, which is not. In Connecticut, for example, although the state has developed regulations that include mandatory requirements and associated fines as described in section 6.11, anecdotal project team experience suggests that in practice, such regulations are not actively enforced. The degree to which this experience can be extrapolated to other jurisdictions is not known, however various degrees of enforcement can logically be expected.

6.1 International Treaty Under the International Maritime Organization (IMO)

Governing Agencies:

International Maritime Organization (IMO).

Legislative or Guideline Documents:

- Marine Environmental Protection Committee (MEPC) 62 Annex 26, 2011.
- International Convention on the Control of Harmful Anti-fouling Systems on Ships 2001, 2008.
- Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species.

Biofouling Policies:

- Ships should retain a Biofouling Management Plan and record book.
- Ships should use appropriate anti-fouling systems on submerged surfaces, including niche areas.
- Ships should undergo periodic underwater inspections, with cleaning and maintenance as appropriate.
- The design and construction of ships should consider the most appropriate configurations to minimize biofouling and allow access for maintenance.

Current Status:

Application or re-application of organotin-based coatings is prohibited. While this is not a biofouling-specific measure - it refers more directly to marine pollution from biocidal coatings –it has implications for biofouling transfers.

The 2011 guidelines are voluntary and provide best-practice approaches for shippers.

In-water Cleaning Policy:

- In-water cleaning should be carried out with awareness of local authority regulation in the location in question.
- In-water cleaning should minimize the release of biocide to the environment.
- In-water cleaning should avoid damaging the hull coating (and negatively impacting its efficacy).
- In-water cleaning should minimize the release of biota to the environment and incorporate available capture technology.

6.2 United States Federal Government

Governing Agencies:

- United States Coast Guard (USCG).
- United States Environmental Protection Agency (USEPA).

Legislative or Guideline Documents:

- National Invasive Species Act, 1996.
- Code of Federal Regulations - 33 CFR 151, Subpart D, Section 2050: Additional Requirements – nonindigenous species reduction practices.
- Vessel General Permit (VGP) for discharges incidental to the normal operation of vessels, authorization to discharge under the National Pollutant Discharge Elimination System (NPDES), under the provisions of the Clean Water Act (as amended 33 USC [United States Code] 1251 et seq.).

Biofouling Policies:

From 33 CFR 151-2050, regulated by the USCG:

- Rinse anchors and anchor chains when the anchor is retrieved to remove organisms and sediments at their places of origin.
- Remove fouling organisms from the vessel's hull, piping, and tanks on a regular basis and dispose of any removed substances in accordance with local, State and Federal regulations.
- Maintain a vessel-specific management plan (under ballast water management rules) on board the vessel that includes detailed fouling maintenance and sediment removal procedures.

From the VGP, regulated by the USEPA:

- Antifouling hull coatings & hull coating leachate: Hull coatings must meet the requirements of the Clean Hull Act (2010); hull coatings must not contain biocides or toxic substances banned for use in the U.S.; consideration must be given for the most appropriate coatings with the lowest biocide release rate, rapid biodegradable components, or non-biocidal alternatives; vessels that reside or operate >30 days in copper impaired ports or harbors shall consider alternatives to copper-based coatings or justify why copper-based coatings are used; there is a zero-discharge standards for organotin (including TBT).
- Cathodic protection: Sacrificial anodes (used to prevent corrosion) should be designed and constructed to minimize the accumulation of biofouling hotspots.
- Anchor chain and chain locker effluent: Anchor chains must be thoroughly washed as they are being hauled out of the water to remove sediment and marine organisms; chain lockers must be thoroughly cleaned during drydocking; chain lockers should be periodically cleaned and pump-out (preferably in mid-ocean) and vessels that leave U.S. waters are not permitted to discharge chain-locker effluent into U.S. waters.
- Seawater piping biofouling prevention: Seawater piping biofouling chemicals subject to Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration must be used in accordance with their FIFRA label; no chemicals or pesticides banned for use in the U.S. may be discharged as part of seawater piping systems; owner/operators must use the minimum effective amount of biofouling chemicals to treat piping systems; discharges containing active agents must contain as little chlorine as possible; fouling organisms must be removed from seawater piping on a regular basis and disposed in accordance with local, state and federal regulations; removed fouling organisms shall not be discharged into U.S. waters; vessels should remove organisms while at sea where feasible to reduce the risk of invasive species introduction in ports.
- Underwater ship husbandry and hull fouling discharges: Owners/operators must minimize transport of attached living organisms when traveling to U.S. waters from outside of U.S. waters or between Captain of the Port (COTP) zones; management includes using an appropriate anti-fouling system, in-water inspections, cleaning and maintenance, and thorough hull and niche area cleaning in drydock; rigorous hull cleaning should occur on drydock or other land-based facility where effluents and biota can be contained; wash water from drydocking should be treated to remove antifouling compounds and organisms prior to discharge into U.S. waters.
- Inspection, monitoring, and recordkeeping: Routine visual inspections (weekly) may involve some biofouling assessment; comprehensive annual vessel inspections must be conducted and include examinations of the hull and niche areas for fouling organisms and flaking anti-fouling coatings; areas not accessible during annual or routine inspections should be recorded and be thoroughly inspected during drydocking; drydock inspection reports must be made available to the EPA upon request; drydock reports must include details of chain locker cleaning, hull and



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niche area inspections and cleaning (removal and neutralization of living organisms), antifouling coating application maintenance and removal.

- **Reporting:** Submit a Notice of Intent (NOI) form in order to be covered under the VGP if a vessel is ≥ 300 gross tons or has the capacity to hold or discharge more than 8-cubic meters of ballast water; submit an annual VGP form to the EPA; both forms include information on drydocking, anti-fouling coatings, and hull husbandry practices.

Current Status:

The USCG updated 33 CFR 151, Subpart D, Section 2050 in March 23, 2012.

The current USEPA VGP runs from December 19, 2013 and expires at midnight on December 19, 2018.

In-water Cleaning Policy:

From 33 CFR 151-2050, regulated by the USCG:

Remove fouling organisms from the vessel's hull, piping, and tanks on a regular basis and dispose of any removed substances in accordance with local, State and Federal regulations.

From the VGP, regulated by the USEPA:

In-water cleaning should involve methods that minimize discharge of organisms and hull coatings, including appropriate brush use and the use of feasible vacuum and other control technologies to minimize the release and dispersion of antifouling coatings and organisms; minimize the release of copper-based paints during vessel cleaning, ensuring no release of a visible cloud or plume; if a cloud or plume occurs as normal practice, ensure no coating compounds are easily detectable in the plume; vessels with copper-based coatings cannot be cleaned in copper-impaired waters within 365 days of coating application (if such an event happens, the reasons for doing so must be documented).

Pending Status or Notes:

Proposed rule changes to 33 CFR 151 being pursued at present relate only to ballast water reporting and do not include amendments to biofouling and hull management.

The current VGP will remain in force until 2018.

6.3 New Zealand

Governing Agencies:

Ministry for Primary Industries, Biosecurity New Zealand.

Legislative or Guideline Documents:

- Biosecurity Act 1993 and subsequent amendments.
- Hazardous Substances and New Organisms Act 1996.
- Anti-fouling and in-water cleaning guidelines, 2013 (Australia & New Zealand).
- Craft Risk Management Standard (CRMS); Biofouling on vessels arriving to New Zealand, 2014.

Biofouling Policies:

- Vessels arriving from outside of New Zealand's territorial waters must arrive in New Zealand with a 'clean hull.'
- The standard applies to all watercraft, inclusive of recreational boats, barges, commercial ships, drilling rigs etc.

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- A hull is defined as all of the immersed (and occasionally immersed) surfaces of a vessel, including niche areas and the wind-and-water line (and pontoons).
- There are two ‘clean hull’ thresholds for long stay and short stay vessels.
- Long-stay vessels (staying for ≥ 21 days) can only have a slime layer and goose neck barnacles across all hull surfaces.
- Short stay vessels (staying ≤ 20 days) can have slime layer and goose-neck barnacles; the waterline, hull areas and niche areas can also have specified (low) levels of algae and incidental coverage of biofouling fauna.
- Acceptable measures for meeting the clean hull requirement include: (a) cleaning the hull of all biofouling less than 30 days prior to arrival or within 24 hours after arrival at an approved facility or with an approved system; (b) continual maintenance using best practice, including using IMO guidelines; (c) applying treatments that have been approved by the Ministry for Primary Industries (MPI).
- Prior to arrival, vessels must report an Advanced Notice of Arrival form and associated documents to MPI.
- Vessels must maintain a Biofouling Management Plan and log and present it to MPI upon request.

Current Status:

New Zealand released its CRMS on May 15, 2014 and it is a voluntary standard until May 2018 when it becomes mandatory.

The guidelines for in-water cleaning (below) replaced the 1997 Australian and New Zealand Environment and Conservation Council (ANZECC) Code of practice for anti-fouling and in-water cleaning and maintenance. These new guidelines were released in June 2013.

In-water Cleaning Policy:

- In-water cleaning is allowed in Australia and New Zealand (joint policy document), but it must be conducted in accordance with local, regional or state regulations.
- If used, in-water cleaning should be conducted as a regular (6-12 month) maintenance practice to maintain surfaces rather than a substitute for an absence of earlier maintenance.
- In-water cleaning is only acceptable when contaminant discharges meet relevant standards set by the governing authority.
- In-water cleaning should be done before departing to new destinations, not after arrival.
- In-water cleaning should only be carried out on coatings for which it is appropriate (based on manufacturer guidelines).
- In-water cleaning should not be conducted to extend the expired service life of a coating; vessels should be removed from the water and a new coating applied.
- Methods of capture for biological debris should be used as much as possible, and cleaning technologies should aim to capture debris of at least 50 micrometers in size.
- If suspected nonindigenous species are encountered during in-water cleaning, the cleaning activity should be ceased immediately and the relevant authority notified.
- A decision support tool for in-water cleaning is included in the guidelines.

Pending Status or Notes:

A voluntary ‘lead-in’ period of four years for the CRMS will expire in May 2018, after which time the standard will be mandatory and enforced. An alternative management plan can be submitted by vessel operators to MPI for approval, but such plans must contain requirements that are equivalent to those

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outlined in the CRMS. The in-water cleaning guidance provides the current status governing this activity in New Zealand (and Australia) but the ministry is pursuing reviews and further research on the subject.

6.4 Australia

Governing Agencies:

Department of Agriculture, Fisheries & Forestry (DAFF).

Legislative or Guideline Documents:

- Quarantine Act, 1906.
- Biological Control Act, 1984.
- National Biofouling Management Guidelines for Commercial Vessels, 2009.
- National Biofouling Management Guidelines for Recreational Vessels, 2009.
- Proposed Australian Biofouling Management Requirements: Consultation Regulation Impact Statement, 2011.

Biofouling Policy:

For commercial vessels:

- Ships' submerged surfaces should be coated appropriately.
- Sea chests should be coated and have operational marine growth protection systems (MGPS).
- Pipes and grates should be rounded and coated.
- Niche areas should be coated appropriately.
- Unpainted niches should be regularly inspected and maintained.
- Internal sea-water systems should have MGPS.

For recreational vessels:

- Maintain trailered vessels on land (including thorough washing and drying of hulls and trailers).
- Clean hulls and gear of biofouling as soon as possible (in-water cleaning is discouraged but the new in-water cleaning guidelines emerged after these 2009 guidelines).
- Use the most appropriate antifouling coatings based on vessel type and voyage profile.
- Clean and/or treat internal sea-water systems.
- Dispose of all cleaning materials (biofouling, effluent, etc.) at approved land-based facilities.
- Retain records of antifouling coatings, maintenance and voyage itineraries.
- Comply with specific requirements related to outbreaks of invasive species (these could include following quarantine measures for boats).
- Be aware of marine pests, report them to relevant authorities, and never release a marine pest back into the water.

Current Status:

The current approach (items listed above) follows the National Biofouling Management Guidelines for commercial and recreational vessels (2009), which are voluntary.

In-water Cleaning Policy:

- In-water cleaning is allowed in Australia and New Zealand (joint policy document), but it must be conducted in accordance with local, regional or state regulations.

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- If used, in-water cleaning should be conducted as a regular (6-12 month) maintenance practice to maintain surfaces rather than a substitute for an absence of earlier maintenance.
- In-water cleaning is only acceptable when contaminant discharges meet relevant standards set by the governing authority.
- In-water cleaning should be done before departing to new destinations, not after arrival.
- In-water cleaning should only be carried out on coatings for which it is appropriate (based on manufacturer guidelines).
- In-water cleaning should not be conducted to extend the expired service life of a coating; vessels should be removed from the water and a new coating applied.
- Methods of capture for biological debris should be used as much as possible, and cleaning technologies should aim to capture debris of at least 50 micrometers in size.
- If suspected nonindigenous species are encountered during in-water cleaning, the cleaning activity should be ceased immediately and the relevant authority notified.

A decision support tool for in-water cleaning is included in the guidelines.

Pending Status or Notes:

Mandatory regulations (2011) await ratification by the Australian Government and these recommended regulations include a risk-based management scheme with management action and associated costs imposed on high/extreme risk vessels.

6.5 Western Australia (Australia)

Governing Agencies:

Department of Fisheries.

Legislative or Guideline Documents:

- Environmental Protection Act 1986.
- Fish Resource Management Act 1994 (FRMA).
- Fish Resources Management Regulations 1995 (FRMR) r176(1).
- Port Authorities Act 1999.
- Port Authorities regulations 2001.
- Western Australian Prevention List for Introduced marine Pests, 2013.
- Western Australia marine pest management guidelines (updated 2014).
- Biofouling Biosecurity Policy 5th May 2014.

Biofouling Policies:

- The policy applies to all vessel types, although there was an initial focus on vessels involved in the extraction industry that were working in sensitive marine areas.
- Vessels should be 'clean' of biofouling before they depart for a Western Australia destination.
- Vessels must maintain a log of operational history since last antifouling coating application or may be required to undergo an Introduced Marine Pest (IMP) inspection.
- Vessels must provide the most recent in-water cleaning or drydocking report, and the most recent IMP inspection report upon request (vessels should depart for WA within seven days of the most recent antifouling coating application or IMP inspection).

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- Upon request, vessels must provide evidence of active MGPS or suitable manual treatments of seawater intakes, pipe-works, sea chests and sea strainers.
- Upon request, vessels must provide the most recent antifouling coating certificate or receipts stating the coating type, volume purchased, vessel name, and date of application.

Current Status:

The requirements listed above are mandatory. The Department of Fisheries has authority to manage biofouling for international, interstate, and intrastate vessel movements in Western Australia.

In-water Cleaning Policy:

In-water cleaning is governed by Australian and New Zealand rules (provided above), which has replaced the ANZECC code.

Pending Status or Notes:

The overall policy of risk-based management is being rolled out progressively, and risk levels are planned for international vessels, out-of-state (domestic Australia) vessels, and in-state vessels.

The policy will be reviewed before May 2016.

6.6 Northern Territory (Australia)

Governing Agencies:

Department of Primary Industry & Fisheries (DPIF).

Legislative or Guideline Documents:

- Fisheries Act 2011.
- Fisheries Regulations 2012.

Biofouling Policies:

- The policy appears to only cover recreational or ‘small’ boats rather than commercial ships and other vessels.
- All yachts seeking entry to Darwin marinas must complete a questionnaire before or upon arrival.
- Visiting vessels (yachts) are subject to in-water inspections if deemed necessary.
- Visiting vessels (yachts) are subject to immediate treatment (in slipways) if deemed necessary.
- Vessels should have internal sea-water systems treated using 1-percent detergent for 14 hours prior to arrival.

Current Status:

The requirements listed above are mandatory for boats wishing to enter Darwin marinas. Only vessels that require inspection or cleaning outside of normal hours (and outside of one location) may incur a fee.

In-water Cleaning Policy:

In-water cleaning is governed by Australian and New Zealand rules (provided above), which has replaced the ANZECC code.

Pending Status or Notes:

N/A

6.7 California State

Governing Agencies:

CSLC.

Legislative or Guideline Documents:

California Code of Regulations, Title 2, Division 3, Chapter 1, Article 4.8.

Biofouling Policies:

- Regulations pertain to vessels >300 gross registered tons capable of carrying ballast water.
- Biofouling must be removed regularly, defined as:
 - No longer than the expiration or extension date of the ship's safety construction certificate, OR
 - no longer than the expiration date of the ship's U.S. Coast Guard certificate of inspection, OR
 - no longer than 60 months since the ship's most recent drydocking.
- Vessels must submit a Hull Husbandry Reporting Form each calendar year if they operate in California during that year.

Current Status:

The existing biofouling requirements are mandatory.

In-water Cleaning Policy:

- In-water cleaning of propellers is permitted in California.
- In-water cleaning of non-toxic foul-release coatings is permitted in California.
- In-water cleaning of surfaces coated with anti-fouling paint (toxic) is allowed only in areas that are not designated as pollution impaired.

Pending Status or Notes:

The CSLC is working on new rule-making documents, which have been undergoing a public comment period. These mandatory regulations include presumed compliance for hull surfaces and niche areas with appropriate and 'in-date' coatings and MGPS with biofouling standards for vessels that fall outside of these presumed standards. There are also proposed requirements for record keeping, reporting, and maintenance action on vessels with extended residency periods.

6.8 Oregon State

Governing Agencies:

Department of Environmental Quality (DEQ).

Legislative or Guideline Documents:

Biofouling threats associated with shipping traffic to Oregon waterways (Michael Paul, 2011) Report to the Oregon Department of Environmental Quality.

Biofouling Policies:

- The Oregon DEQ has authority to regulate ballast water and the former 'ballast water task force' has been re-named as the 'Shipping Transport of Aquatic Invasive Species (STAIS) task force by the Oregon legislature. The Program Officer monitors the biofouling issue and participates in the

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Western Regional Panel on Aquatic Invasive Species Coastal Committee, which coordinates biofouling policy among the Pacific States.

- From Paul (2011): “Oregon law does not explicitly designate commercial vessel biofouling prevention responsibilities to a specific agency, though water quality criteria and wildlife integrity laws (statute/rule citation) would apply to some situations.”
- Oregon Senate Bill 432 (2007): Ship disposal (ship breaking) is not permitted in Oregon waters unless it is conducted on drydock.

Current Status:

The Oregon DEQ manages ballast water and applies a case-by-case approach to biofouling if issues arise.

In-water Cleaning Policy:

In-water cleaning of hulls coated with anti-fouling paint is prohibited in the state.

Pending Status or Notes:

- There is a proposal to update the existing DEQ authority on ballast water (OR [Oregon] 783.620) to include management of biofouling of commercial vessels.
- There is also a recommendation to amend existing reporting requirements to include mandatory annual reporting of hull maintenance and biofouling-related activities.
- There is also a proposal to establish regulations that enables the Oregon DEQ to target high-risk vessels for management action.

6.9 Washington State

Governing Agencies:

- Washington Department of Fish & Wildlife (WDFW).
- Department of Ecology (ECY).

Legislative or Guideline Documents:

- Revised Code of Washington (RCW) 77.15.253 Unlawful use of prohibited aquatic animal species, which also prohibits the release of aquatic animal species classified as “regulated” and “unlisted.”
- An assessment of the biofouling introductions to the Puget Sound region of Washington State. (Reference 6).

Biofouling Policies:

Case-by-case interpretation of RCW 77.15.253.

Current Status:

The current status of biofouling management is based on the case-by-case approach by Washington Dept. of Fish and Wildlife.

In-water Cleaning Policy:

- In-water cleaning of hulls coated with anti-fouling paint is prohibited in the state by ECY.
- In-water cleaning of foul-release and other ‘hard’ non-toxic coatings is permitted on case-by-case basis.

Pending Status or Notes:

A report to WDFW was finalized in 2014 and the recommendations are under consideration. A process of policy development (including public meetings and task force workshops) may be initiated.

6.10 Hawaii State

Governing Agencies:

Department of Land & Natural Resources (DLNR).

Legislative or Guideline Documents:

Act 134, Session of Laws 2000, Chapter 187A Part III, Hawaii Revised Statutes (Alien Aquatic Organisms).

Biofouling Policies:

- DLNR has the authority to adopt rules, including penalties for ballast and hull fouling.
- Questionnaires have been developed and approved to gather data throughout 2014 on vessel biofouling for commercial and recreational vessels.

Current Status:

No specific biofouling requirements exist at present.

In-water Cleaning Policy:

In-water cleaning is governed by the Hawaii Department of Health and is focused on concerns regarding biocide release (water quality) rather than release of organisms. Hawaii is conducting a data gathering exercise to establish the status quo for in-water cleaning in state waters.

Pending Status or Notes:

Hawaii DLNR is in a process of information gathering and analysis regarding biofouling patterns and practices in the State. A report is due in early 2015 on this topic and further policy proposals may result from this process.

6.11 Other U.S. States

Hull Fouling Policies:

None of the other U.S. coastal states we contacted had a specific policy on hull fouling. Many states have regulations that prohibit the importation, possession, movement, and/or release of certain non-native species, which could potentially be amended to regulate hull fouling generally. Some states, such as Florida, prohibit the release, transport, or introduction of any non-native species without a permit. More commonly, states tend to prohibit specific animal species, typically the best-known freshwater nuisance species, such as the zebra and quagga mussels. In many cases specific freshwater plants, such as hydrilla and water hyacinth, were also listed, but in some instances (such as in Connecticut, General Statute 15-180) all aquatic vegetation is listed as prohibited.

In-water Cleaning Policies:

Most state agencies had specific regulations in place regarding the disposal of wastewater from out-of-water hull cleaning, including solids, in accordance with state and Federal EPA regulations on discharges into water bodies. These regulations were aimed at commercial boatyards as well as small marinas, and required that all waste materials be captured, contained, and disposed of in a land-based

refuse system. None of the states had explicit bans on in-water cleaning, although many said this practice was discouraged, and that technically the use of detergents (except for nontoxic, biodegradable types) or chemicals in the water is prohibited, as would be the creation of a cloud or plume generated by paint removal resulting from scrubbing in water. State officials referred to guidance documents contained in Clean Marinas program materials

Recreational boaters

Connecticut, New York, and Texas have regulations requiring that boaters remove plants and animals from boats and trailers traveling between waterways; boaters who do not do so can be fined. Texas and New York State also require boaters to “drain, clean and dry” upon leaving a water body. Connecticut specifically requires removal of listed invasive animal species and all aquatic vegetation, while New York’s regulations apply to all animal species (other than pets, legally allowable bait, and game species) but only to invasive plants, and the rules in Texas only apply to harmful non-natives. The New York regulations apply only at launches managed by the state Department of Environmental Conservation and the Office of Parks, Recreation and Historic Preservation (Title 6 NYCRR [New York Codes, Rules and Regulations] Part 59, section 59.4; Title 9 NYCRR, section 377.1(i). New York State is in the process of promulgating regulations defining reasonable precautions for cleaning. Connecticut’s laws also require the teaching of the proper means of inspecting and disposal of such species in state-approved boater safety courses.

All states had some form of boater education/outreach about ANS. These efforts included information on state websites and study guides for boater certification courses, collaborations with local Sea Grant offices and/or universities, and the Clean Marina program, signs at marinas and boat launches and other outreach materials to the boating public. Many states promote BMP for commercial boat cleaners and for recreational boaters, which include removing macro organisms and washing boats and trailers. Nearly all of these efforts are focused on trailered boats moving between waterways rather than on boats kept in saltwater.

Commercial ships

None of the states we contacted had their own rules, guidelines, or outreach materials aimed at the commercial shipping or fishing sectors. Many of the people we talked with at state agencies mentioned that regulation of commercial vessels was the responsibility of the Coast Guard and/or Federal EPA; a few states, such as Massachusetts, made information on the federal regulations on commercial ships available on their websites. Some states, such as Maryland and Virginia, have incorporated some USCG regulations into state law.

6.12 Papahānaumokuākea Marine National Monument (PMNM), Northwestern Hawaiian Islands

Governing Agencies:

- National Oceanic & Atmospheric Administration (NOAA).
- United States Fish & Wildlife Service (USFWS).
- State of Hawaii Department of Land and Natural Resources.

Legislative or Guideline Documents:

- Presidential Proclamation 8031, 2006.
- Code of Federal Regulations, Title 50, Part 404.
- PMNM BMP-001 Marine Alien Species Inspection Standards for Maritime Vessels, 2009.

Biofouling Policies:

- It is unlawful to introduce or otherwise release an introduced species from within or into the Monument.
- All vessels wishing to enter the Monument must obtain an entry permit; part of the permitting process includes inspection for alien species (including vessel hull, tender, gear, ballast water, and rat surveys).
- There is strict control over entry to the monument and strict standards for biofouling (no macro-algae and no macro-invertebrate biofouling).
- Vessel hull, tenders, gear, and ballast water must be certified free of alien and invasive species prior to departure for the Monument.

Current Status:

The requirements for entry to the Monument are mandatory and strictly enforced.

In-water Cleaning Policy:

In-water cleaning of vessels is prohibited in the Monument.

Pending Status or Notes:

N/A.

6.13 Galapagos Marine Reserve (GMR)

Governing Agencies:

- Galapagos Biosecurity Agency (ABG).
- Galapagos National Park Directorate (GNPD).

Legislative or Guideline Documents

N/A (currently being revised).

Biofouling Policies:

- Boats are required to have their hulls cleaned before entering the GMR.
- Boats are required to submit to a visual inspection, which may include in-water inspection by diver, upon arrival by the ABG and GNPD.
- If a boat is found to have any encrusting organisms, the GNPD has the authority to demand the vessel leave the GMR.
- Policy applies to all vessel types, foreign and domestic, arriving from outside the GMR.

Current Status:

In effect and mandatory.

In-water Cleaning Policy:

Locally based boats are allowed to clean in water; other vessels must clean 60 miles outside the marine reserve.

Pending Status or Notes:

More detailed guidelines and refined regulations are being worked on by the ABG and GNP. These were expected to be completed approximately by the end of 2014. Among the expected changes are:

- The development of an environmental risk assessment for each vessel, which will help the enforcement agencies prioritize inspections.
- Guidelines regarding the extent and type of biofouling that can be allowed into GMR.
- Guidelines and protocols for a rapid response in the event of a new invasion.

6.14 Secretariat of the Pacific Regional Environmental Programme (SPREP)

Governing Agencies:

Member countries

Legislative or Guideline Documents:

Model legislation, Model Marine Pollution Prevention Bill (with Ballast Water Convention Provisions); larger strategy, Shipping-related Introduced Marine Pests in the Pacific Islands: A Regional Strategy.

Biofouling Policies:

SPREP has prepared model legislation that:

- Adopts the IMO guidelines for member countries.
- For ships of 400 gross tonnage and above traveling internationally, requires surveys to be made before a ship is put into service or before first issue of the International Anti-Fouling System Certificate, and after changing or replacing a system.
- Requires that ships greater than 24 m but less than 400 gross tonnage traveling internationally carry a Declaration on Anti-Fouling Systems, with additional documentation (such as receipts for paint or contractor invoices) to verify its contents.
- Grants inspectors the right to inspect records, test systems, and board vessels.
- Grants countries the right to refuse entry of vessels found to be in violation of any of the above provisions.

Current Status:

Legislation is currently advisory/voluntary.

In-water Cleaning Policy:

SPREP's model legislation would effectively ban in-water cleaning of vessels unless this could be done in a manner that ensures that non-native species are not introduced into a country's waters. It would also require containment and disposal of scraped material from cleaning done on land.

Pending Status or Notes:

The SPREP strategy for biofouling also includes the following recommendations for member countries:

- Adopt model legislation consistent with the IMO regulations addressing anti-fouling paint types, ballast water discharge, and biofouling and incorporates practical management measures.
- Engage with the IMO and Pacific Rim nations (major source of ship and boat arrivals to Pacific Island countries) to reduce biofouling on vessels pre-departure through the use of best-practice fouling prevention and control measures.
- Require pre-departure inspections of hull and mandatory cleaning to ensure boats are free of fouling.
- Adopt at-border management measures including: an assessment to identify and intercept high-risk vessels; inspections at first port of call for internationally traveling yachts; and prompt action to remove small vessels from water for cleaning if non-native species are detected.
- Develop rapid response, control, and mitigation measures in cases of establishment of a new marine pest.



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Trainings on compliance monitoring and enforcement have been conducted in the Solomon Islands and Vanuatu. Further development and implementation of strategy is stalled pending funding.

6.15 Scotland

Governing Agencies:

Scottish Natural Heritage, Scottish Environmental Protection Agency, Forestry Commissioners.

Legislative or Guideline Documents:

- Wildlife and Countryside Act 1981, amended in Wildlife and Natural Environmental (Scotland) (WANE(S)) Act 2011 (asp 6).
- Code of Practice on Non-Native Species.
- Marine Biosecurity Planning: Guidance for producing site and operation-based plans for preventing the introduction of non-native species.

Biofouling Policy:

- Importing, moving and releasing or allowing the release of non-native biofouling animals or plants is a punishable offense.
- Authorities must be notified of the presence of a non-native species.
- Individuals and organizations are required to carry out due diligence and follow best practices to prevent the introduction and spread of non-native species.
- As far as we were able to determine, despite the above regulations, there is no explicit policy addressing commercial ships.

Current Status

Mandatory.

In-water Cleaning Policy:

As far as we were able to determine, there currently is no explicit policy on in-water cleaning. However, given the above recent legislation, it is reasonable to expect that this practice will be discouraged if not eventually prohibited.

Pending Status or Notes:

Updates to the WANE(S) Act are recent, and we were unable to determine how they may be enforced. It appears that at this time agencies are encouraging prevention through BMP.

6.16 Summary of Biofouling Policy

The list of governments and relevant authorities actively involved in biofouling management at a policy level has grown rapidly in recent years, and policies range from voluntary international guidelines to specific mandatory requirements at regional levels. The emergence of biofouling policies has occurred in response to growing evidence that (a) ballast water management is relatively advanced and is likely to have the desired effect of reducing ballast-mediated invasions; (b) marine invasions from vessel biofouling are an enduring concern and may undercut any gains achieved from ballast water management; and (c) despite significant maritime industry investment in biofouling prevention for the purposes of propulsion efficiency (fuel costs), broader policies are required to manage biosecurity risks.

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While the current list of entities regulating biofouling is still relatively small, awareness of biofouling as a major vector of non-native species transport is growing worldwide. More countries and regions are expected to develop regulations in the near future. To illustrate, two recent scientific papers from Singapore (Reference 30) and Japan (Reference 23) each address the contribution of biofouling to marine invasions in their respective regions. Studies of biofouling on recreational boats are underway at the University of Capetown, South Africa, and the University of Pavia, Italy; and several meetings have been held to examine the role of biofouling in invasions in the Antarctic.

Changes to biofouling policies and/or development of new regulations are anticipated over the next several years. Table 7 is a summary timeline of pending changes:

Table 7. Pending changes to global biofouling management regulations.

Entity	Policy updates	Anticipated completion
Galapagos Marine Reserve	Refinements to biofouling policy; to include risk-assessment approach; definition of allowable biofouling	2014
Hawaii	Analysis of data on biofouling on commercial; recreational vessels	2015
CA	Comment period on new regulations closes; revised rules move forward	2015/16
Western Australia	Review of risk-based management policy to be completed	2016
New Zealand	Voluntary regulations become mandatory	2018

Summary of Biofouling Policy in the U.S.

- Commercial vessels visiting the United States must manage biofouling to operate under U.S. Coast Guard regulations and the Vessel General Permit (VGP overseen by the USEPA). The existing USCG rules are minimally descriptive and do not define “regular maintenance.” The VGP is more descriptive of biofouling management guidelines although it is not clear how enforcement is assessed under the general permit approach.
- Regulations aimed at recreational vessels focus almost exclusively on boats trailered between water bodies, and almost exclusively on a small suite of freshwater species. In most cases, efforts directed at boaters are informational guidelines rather than mandatory rules.
- A federalist approach to biofouling management in the U.S. gives the states some latitude to manage their own biosecurity while providing a testing ground for policies whose efficacy can be evaluated over time. The West Coast states are most active and protective from a biosecurity perspective. A similar approach exists in Australia at present. Although there is overlap among the states that implement their own policies (or are intending to), commercial shipping groups have commented that such an approach allows for too much variation in regulatory requirements among states, which increases their burden of management and reporting.
- Fishing vessels and other types of smaller commercial craft are mostly not addressed, either by federal rules or by outreach and educational efforts aimed at recreational boaters.
- Cleanings that are more frequent are one way in which vessels can potentially meet new regulations and standards. However, in-water cleaning, which is more cost-efficient than drydocking, is banned outright or is actively discouraged in many locations based on concerns about the release of both chemical pollutants and non-native species.

7 COST OF REGULATORY ACTIONS

While the costs of biofouling are significant, the cost of sound biofouling management practices may be offset by improved environmental stewardship and reduced vessel operating costs. This section provides examples of costs that result from recently enacted or proposed regulations. The list is not all-inclusive, as the figures have not been fully developed in many cases.

A number of obstacles make it difficult to accurately analyze such costs. For example, commercial operators are often reluctant to discuss operating costs, and governmental efforts undertaken to support proposed legislation may introduce bias. Whether government cost figures differ from industry estimates must often be gauged through review of the lengthy comment process associated with proposed regulations. In addition, it is often difficult to determine whether costs should be attributed to regulatory requirements, or sound business practices, such as cleaning the hull to reduce fuel cost, or whether the cost should be allocated between the two.

7.1 California State Lands Commission

In 2011, the CSLC published a NPRA (Reference 4) to solicit public comments on a proposal to establish performance standards for biofouling management for vessels calling in California ports. As part of that NPRA, the CSLC developed what is probably the most thoroughly researched estimate of costs attributed to biofouling regulation. The following paragraphs are extracted from Reference 4.

The potential costs associated with the proposed regulatory action relate to several provisions in the proposed regulations. The costs associated with inspection and maintenance of the wetted surfaces to meet the performance standards for biofouling management are dependent on the current frequency of a vessel's maintenance practices. At a bare minimum, most vessels are already required by the International Convention for the Safety of Life at Sea (SOLAS) to undergo out-of-water maintenance every five years. Commission-collected data indicates that the average vessel arriving to California undergoes out-of-water maintenance more frequently than this minimum. In 2008 and 2009, approximately 67 percent of vessels had been drydocked or delivered as new within the prior two years, and 84 percent within the prior three years. Additionally, most vessels are required by classification societies to undergo an intermediate survey [hull inspection] approximately 2.5 years after the out-of-water maintenance. In addition, many vessel owners or operators elect to undertake additional in-water cleaning or propeller polishing in order to remove biofouling from the vessel to reduce biofouling-induced drag, the associated decrease in fuel efficiency, and the consequent increase in fuel costs. Propeller polishing is typically conducted as a first measure to address fuel efficiency, often conducted every six months, and often includes a biofouling evaluation of the other underwater surfaces. Several shipping companies have indicated that they undergo propeller polishing and/or in-water inspection on a six-month interval. One company indicated that propeller polishing frequency is dependent on the vessel charterer; some request propeller polishing every six months, others every twelve months, and still others do not request propeller polishing until the intermediate inspection or the out-of-water maintenance. A regional maritime trade association indicated that it is the intent of its members to arrange for inspections on a six-month basis, but this is influenced by vessel type and trade lanes. Finally, a single company indicated that its vessels undergo hull cleaning every three years.

The estimated costs associated with the requirement to evaluate biofouling every six months (or within twelve months of out-of-water maintenance) ranges between “no impact” for vessel owners that currently undergo this type of maintenance on a six month interval to between \$4,000 and \$6,500 per vessel per

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survey. Therefore, the per-vessel cost of the required biofouling evaluations will likely be: 1) no impact if vessel is already inspected or undergoes propeller polishing on a six-month interval; 2) \$4,000 - \$6,500 per year if a vessel is on a 12-month inspection/polishing schedule (i.e. one additional evaluation per 12 months); or as much as 3) \$6,400 - \$10,400 per year for vessels that currently do not conduct any underwater maintenance other than the currently required intermediate survey (i.e. up to four additional evaluations totaling \$16,000 - \$26,000 over the 2.5 year period). One company indicated that if they were required to remove their vessel from service for an entire day to conduct the inspection, it would cost an additional \$50,000 due to the loss of a day of service. However, this assumes that the vessel would need to be removed from service for an entire day in order to conduct an inspection or propeller polishing. The same company also indicated on three separate occasions that their vessels undergo inspection or propeller polishing on a six-month frequency, thus not requiring any additional evaluations to meet the proposed regulations. This company later revised their frequency to every twelve months.

Several studies [References 21, 26, and 28] indicate that the potential costs associated with increased frequency of inspection or cleaning may be offset by a larger fiscal benefit from maintaining lower levels of biofouling. Increased levels of biofouling contribute towards increased hydrodynamic drag, reducing the fuel efficiency, and ultimately resulting in elevated fuel consumption and operating costs. Proper maintenance of biofouling will result in lower operating costs, and studies suggest that the fuel savings would far outweigh the potential maintenance costs (References 13, 21, and 26). Reference 26 evaluated costs associated with mid-sized U.S. naval surface ships using the U.S. Navy fouling rating system (FR), which at lower biofouling levels is consistent with the Level of Fouling ranking scale proposed in these regulations. The authors determined that a decrease from FR 30 (equivalent to the proposed Level of Fouling rank 2) to FR 20 (equivalent to the proposed Level of Fouling rank 1) would result in savings of approximately \$300,000 to \$400,000 in fuel costs per ship per year. These estimates were developed based on a mid-sized naval surface vessel so the exact savings may not be directly equivalent to the average merchant vessel, but the principles would be similar and there would undoubtedly be significant financial benefits to a vessel that was maintained to a Level of Fouling rank 1. Reference 28 indicates that even a layer of microfouling (Level of Fouling rank 1) on a typical commercial cargo vessel traveling at twenty knots would result in an additional \$4,500 per day in fuel costs. This would equate to over \$1.6 million for a single vessel if employed a full year.

There may also be costs associated with the development and maintenance of the required Biofouling Management Plan and Biofouling Record Book. Several companies have indicated that although there would be some costs associated with the development of these documents, most of the information is already kept onboard or as part of the Ship Management System. In these cases, the costs are expected to be minimal. One company indicated that it would cost \$4,000 per vessel to develop the BMP and Biofouling Record Book. Finally, several companies have indicated that the development of the two documents would require 80 person-hours, and the ongoing management and training would require 200 person-hours per year, with costs dependent on variable person-hour costs.

Companies, which own or operate multiple vessels, should be able to spread the cost of developing multiple sets of documents across these vessels resulting in reduced per-vessel costs. Additionally, both the Biofouling Management Plan and Biofouling Record Book proposed in these regulations are also part of the IMO's Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species. Although the IMO Biofouling Guidelines are voluntary, it is reasonable to assume that responsible owners and operators will adopt the guidelines and develop these documents, whether or not they are mandatory in California.

[California Code of Regulations] Section 2298.6, pertaining to the small minority of vessels remaining in one location for ninety days or greater may also have costs associated with it; however these costs will only be associated with a small percentage of the California fleet. In 2009, only 1.7 percent of the fleet reported remaining in one location for ninety days or greater following their most recent out-of-water maintenance. The costs for this specific regulation depend on the severity of the biofouling associated with the vessel and may range from \$4,000 to \$6,500 for in-water inspection, \$19,000 to \$27,000 for in-water cleaning, \$150,000 to \$800,000 for out-of-water cleaning, or \$300,000 to \$1,200,000 for full out-of-water maintenance (including repainting). These cost ranges for these options are wide and the exact amount is dependent on the size and type of vessel. However, any costs incurred to comply with this regulation may be recouped (possibly surpassed) through fuel savings as a result of the decrease in biofouling-induced hydrodynamic drag, as discussed previously.

Finally, there may be minor costs associated with completing and submitting the Hull Husbandry Reporting Form. However, mandatory annual submission of this form has been required from every vessel operating in California since 2008. Therefore, there should be no significant increase in costs to continue to comply with this requirement.

7.2 U.S. Environmental Protection Agency (EPA)

As part of the sVGP program, the EPA developed cost estimates for various aspects of program implementation. Based on a vessel count of 114,996 (low) to 137,583 (high) the total projected per-year cost of vessel hull maintenance activities ranges between \$2.6 million and \$3.8 million, depending on the vessels included in the universe and the low and high unit costs. The annualized cost of materials (tarps to contain organic material removed from hull surfaces) is estimated at \$300,000 per year, thus the bulk of the cost stems from inspections to prevent the spread of invasive species for vessels that move overland. Recordkeeping costs are estimated at one-half hour per year, or \$1,938,833 to 2,319,649 for the same population.

7.3 Lake Tahoe, CA

Lake Tahoe, CA has regulations in place that require motorized craft to be inspected for NIS at a cost of \$30 USD prior to launch. Vessels that fail inspection are required to undergo a \$35 decontamination process (\$10 additional for ballast tanks) to pass inspection.

7.4 Industry Estimates

One large dive company estimated that the prohibition against hull cleaning in the Port of Long Beach necessitating offshore cleaning, which increases cost 40-percent over dockside cleaning for large (> 300 feet) vessels. The cost increase is due to the extra travel time, fuel cost, and personnel. In addition to the workboat, a ‘fast boat’ is required to run lines and stand by to provide medical evacuation. Offshore conditions can increase the time required to complete the work, or at times, make it impossible.

Innermost Containment Systems LLC (Reference 14) is currently a one-man operation performing commercial hull cleaning on a small scale in Monterey Bay (see section 5.2.3.1) with approval from the Monterey Bay RWQCB. They estimate that containment and filtration apparatus necessary to achieve BAT performance add approximately \$150-\$200 to the cost of cleaning a moderately fouled hull less than 80 feet in length. The additional cost is due to the requirement for a dockside person to manage the filtration system and local hazardous material disposal fees.

8 CONCLUSIONS

This report summarizes the latest technology and regulatory developments related to the prevention of harbor pollution and alien species transfer caused by in-water hull cleaning of biofouling. Considerable progress has been made in recent years, as the attention of regulators has focused on biofouling as a vector for invasive species, in addition to the longstanding emphasis on ballast water management. Progress has also been driven by a shift in hull coating strategies towards a focus on durability and ease of cleaning, and away from bio toxic approaches. The information in this report is as complete and up to date as is practical, with the understanding that both the regulatory environment and the state of technological development are constantly changing. This change follows a growing awareness that the lack of effective biofouling management practices may nullify the progress being made in the area of ballast water management practices and regulations.

8.1 Regulatory Environment

The current state of biofouling regulation remains fragmented from international levels to local jurisdictions within the United States. Entities have taken one of two general approaches to biofouling management, developing policies that either, 1) recommend and/or require hull management regimes, or 2) require that vessels arrive with “clean” hulls (usually in addition to requiring specific maintenance practices). The IMO, the USCG, Australia, and California are examples of the first approach, requiring a set of anti-fouling practices and ships documentation, and in some cases (California, Australia), also specifically requiring removal of fouling “on a regular basis.” The underlying assumption behind this approach is that these specified (or sometimes unspecified) anti-fouling practices are sufficient to reduce biofouling risks to an acceptable level. It is unclear whether this assumption is correct, but these types of regulations are more likely to be accepted by the shipping industry and compliance can be more readily documented.

The second approach, taken by entities such as the PMNM, the GMR, New Zealand, and Western Australia, requires that vessels must be clean on arrival. A major challenge with this approach is defining “clean.” The PMNM defines clean as no macrofouling. New Zealand has two definitions of clean, allowing a slime layer and gooseneck barnacles for long-stay vessels, and a small amount of macrofouling for short-stay vessels. The GMR currently does not allow any “encrusting” organisms, but is in the process of refining its definition of a clean hull. These types of standards are more difficult to enforce and evaluate, requiring standardized inspection protocols that have yet to be devised and implemented. In some cases, there are measures that ships must undertake for falling below the standard. These can be difficult for vessels to achieve, in light of a growing trend to disallow in-water cleaning, but may be more appropriate in areas of high conservation value such as marine preserves.

Several entities have already accomplished or are moving towards a risk-based management scheme, which recognizes that not all vessels pose the same level of biofouling threat. Focusing enforcement efforts on vessels that pose the highest risk allows agencies to make more efficient use of limited resources. Risk-based management can be as simple as New Zealand’s different standards for long-stay vs. short-stay vessels (above), or for international, inter-state, and within state vessel movements (Western Australia). This approach can be used to focus inspections on vessels determined to be high-risk, based on ship behavior, type, age of anti-fouling paint, etc. (already a component of several of the policies reviewed here), or may be used to guide the development of policy that applies most regulatory pressure on vessel characteristics deemed to be the riskiest.

Most entities appear to have the legal authority to regulate biofouling, either very broadly, as a pollutant or hazardous substance (U.S. EPA, New Zealand), or as a threat to biosecurity due to the likelihood that biofouling contains non-native species (New Zealand, Scotland, several U.S. states). Other entities appear to be restricted by legal codes, allowing actions only to stop specific prohibited or pest species (Australia, several U.S. states), which may limit their ability to address the vector as a whole.

In other cases, the arrival of vessels or structures deemed by officials to be especially risky have been managed on an ad-hoc basis outside of normal regulatory channels. An example is the actions taken to prevent the unscheduled entry of a heavily fouled drydock from Chile into Honolulu Harbor, while its tugboat was undergoing repairs (Reference 8). While such actions represent excellent examples of cooperation between jurisdictions and private and public entities, and may have prevented the transfer of non-native species into sensitive areas, these types of individual initiatives cannot be relied upon to address biofouling over the long term. Attempts to regionalize regulatory approaches to in-water cleaning, as seen on the West Coast of the U.S., with CA, OR, WA and HI, offer the hope of a more uniform set of requirements, once the process comes to a conclusion.

8.2 Technological Evolution

Hull cleaning technology, particularly in the areas of “gentle” biota removal and capture/filtering of the cleaning effluent stream is developing rapidly under the auspices of both government and private entities. However, regulators, particularly in the U.S., have been reluctant to create performance standards or to certify systems for use in harbors. Without performance standards, vendors are left to develop systems in a vacuum, and at considerable expense, hoping that commercial markets will open in the near future.

Hull cleaning practices are changing focus from managing the depletion of ablative, toxic compounds to frequent cleaning of minor buildups, with the understanding that hull coatings and hull cleaning methods will have to evolve accordingly. As a result, hull coating manufacturers are abandoning toxic antifouling coatings in favor of silicon based compounds that resist attachment, but require special care when cleaning, and epoxy coatings that are extremely durable and can withstand frequent cleaning.

A number of new approaches have been tested and others are under development or improvement. However, due to the developing nature of regulatory initiatives in many areas as described above, commercial solutions progress at a slow pace or are stalled awaiting the enactment of regulations. The process can take many years to arrive at a conclusion, as iterations of regulatory proposals, industry comments, and technological innovations come and go.

8.3 Regulatory Cost of Biofouling

Numerous difficulties exist with estimating biofouling regulatory cost. One primary difficulty is the state of flux with current regulations, which has left industry without clear requirements or in some areas, a total ban on in-water cleaning, pending enactment of comprehensive regulations. Some of the more extensive efforts to develop such cost estimates have been undertaken as part of the administrative process for proposed regulations. Such information, even if accurate, reflects regulations that are under consideration, not actually in place. In addition, allocating costs between those attributed to regulatory requirements and those undertaken for normal business reasons, such as reducing fuel cost, is highly subjective. Finally, for various reasons, many business professionals in the shipping industry, as well as those developing potential biofouling solutions, are often reluctant to provide cost data. For all the above reasons, estimates of biofouling regulatory costs are subjective, and vary widely.

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